1982

Heavy metal distribution in the sediments of Flathead Lake Montana

Christopher J. Murray

The University of Montana

HEAVY METAL DISTRIBUTION IN THE SEDIMENTS OF FLATHEAD LAKE, MONTANA

by

Christopher J. Murray

B.A., University of Montana, 1980

Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1982

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

Date 6/2/82

ABSTRACT

Murray, Christopher J., Spring, 1982 Geology

Heavy Metal Distribution in the Sediments of Flathead Lake, Montana

Director: Johnnie N. Moore

Flathead Lake and its drainage basin in Montana are now largely unspoiled, but developmental pressures in the area are increasing. The study of sediment geochemistry, particularly of extractable metals, has been used previously to monitor the environmental status of lakes and their drainage basins. In this study, the concentrations of acetic acid extractable, and of total Fe, Mn, Zn, and Cu were determined in the oxidized and reduced layers of the top 15-20 cm of sediments at 110 sites. The amounts of residual and total Cu in the sediments are much greater than those in most freshwater amd marine sediments, and may result from the presence of detrital Cu minerals in Flathead Lake sediments. The highest concentrations of extractable Zn occur near developed areas of the shoreline, particularly in restricted bays. This and other evidence points to ongoing pollution around the lakeshore, presumably by sewage contamination of surface and ground water. The distributions of Mn, Fe, and phosphorus all indicate that early diagenesis occurs in the sediments of Flathead Lake, with Mn and phosphorus migrating from the reduced sediment layers up into the upper oxidized layer. The Fe and Mn oxides now present in the oxidized layer appear to trap large quantities of phosphorus (the limiting nutrient in Flathead Lake) and of certain metals. If the current pollution problems increase to the point that the bottom waters in the lake are no longer oxidizing, the Fe and Mn oxides would no longer be stable. The surface sediments might then become a source, and not a sink, for both metals and nutrients, worsening any developing pollution problems. This study points to the need, and provides a data base, for continued monitoring of Flathead Lake and its drainage basin.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF ILLUSTRATIONS

Page

INTRODUCTION

Flathead Lake is a large freshwater lake, covering 462.3 sq. km. in the Rocky Mountains of northwestern Montana (Potter, 1978). The drainage basin of the lake occupies 18,400 sq. km. (Potter, 1978) in Montana and southeastern British Columbia (Fig. 1). Argillites, quartzites, and carbonates of the Proterozoic Belt Supergroup dominate the bedrock geology of the drainage basin. Cultural development of the basin has been slow, with a small population, and an economy based on logging, farming, and catering to the tourist industries. Flathead Lake is the largest natural freshwater lake west of the Mississippi River (Joyce, 1980). Considering its size and long history of use, the lake remains largely unpolluted.

Recently, however, development in the drainage basin has increased dramatically. Exploration for coal, oil and gas are underway throughout this part of the Rocky Mountain Overthrust belt. Development of known energy resources has either begun, or is in the planning stage. For example, Rio Algom Ltd. has applied for permission to begin strip mining coal at its Cabin Creek property on a tributary of the Flathead River in British Columbia. Minerals companies have been exploring the drainage basin for base and precious metals, economic deposits of which have been found in the sedimentary rocks of the Belt Supergroup west of the Flathead Lake drainage basin. These activities, along with the general trend of population growth in the

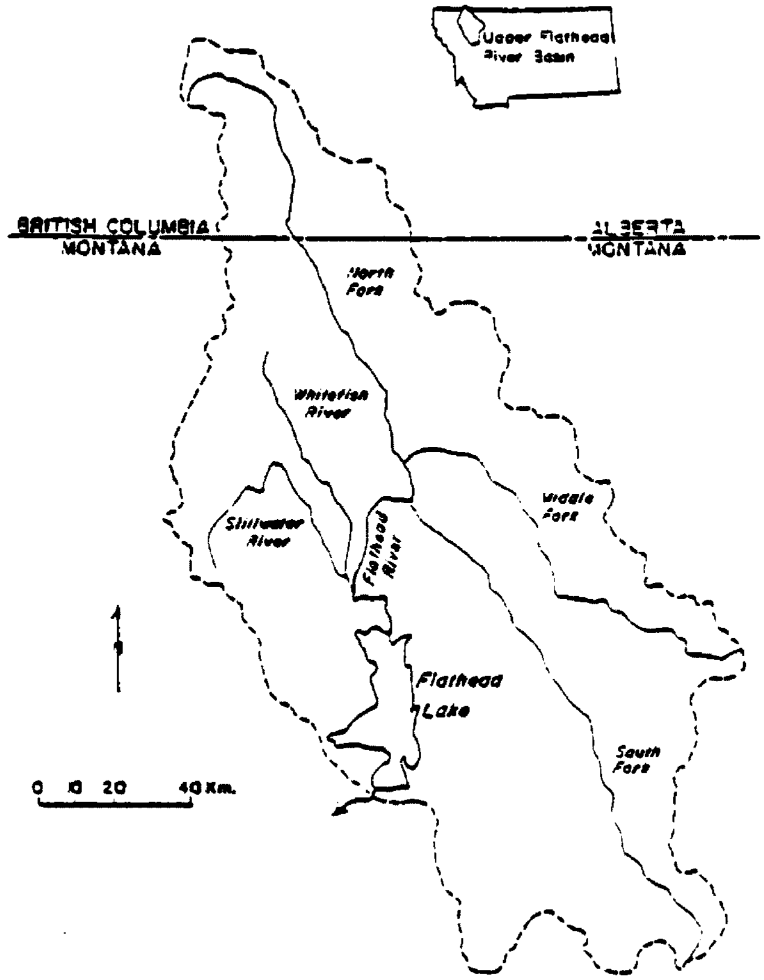

Fig. 1. Location of watershed draining into Flathead Lake.

Rocky Mountains, have increased residential pressure on the area, with concomitant increases in sewage, automotive pollution, and erosion (Potter, 1978).

The study of sediment metal contents has been used previously to monitor the environmental health of aquatic systems (Forstner, 1982b; Crecelius et al., 1975; Goldberg et al., 1981). The study of extractable metals is particularly applicable. Extractable metals reflect the metal content of the sediment that is readily available to the biota. The purpose of this study was to document the present levels of extractable Fe, Mn, Cu and Zn in the lake sediments, and to interpret the geochemical factors controlling their distribution. That knowledge may be useful to future researchers in studies of Flathead Lake and its drainage basin, and in monitoring the effects of present and future development.

METHODS

Sampling and Preparation

Sampling was performed at 110 sites during the summers of 1980 and 1981 (Fig. 2). Surface sediment samples were taken with a Peterson clamshell dredge. Wherever possible, subsamples were taken from the upper oxidized sediment layer, and the lower reduced layer. These layers were recognized by a distinctive color change from gray in the reduced layer to a rust brown color in the oxidized layer (Price, 1976; Berner, 1981). The separation of these subsamples was usually not possible in coarser, sandy areas, such as the Flathead River delta. The samples were stored in clean polyethylene containers, and refrigerated at approximately 4^{o} C.

Extraction

After drying, the samples were extracted with a solution of 20% acetic acid. The metals released by this extraction are weakly bound to the sediment, for example, in pore water, cation exchange sites and carbonates, and physically adsorbed to mineral and organic sediment. The metals bound in this fashion are assumed to be readily available to the biota if the chemical environment of the sediment changes (Skei and Paus, 1979). The extraction was performed by placing one gram of sediment with 25 ml of 20% acetic acid in a Nalgene Screw-Cap test tube, which was then placed on a mechanical shaker for 12 hours. After centrifuging, the supernatant was decanted into Nalgene bottles, which were kept at 4^{o} C until the samples were analyzed.

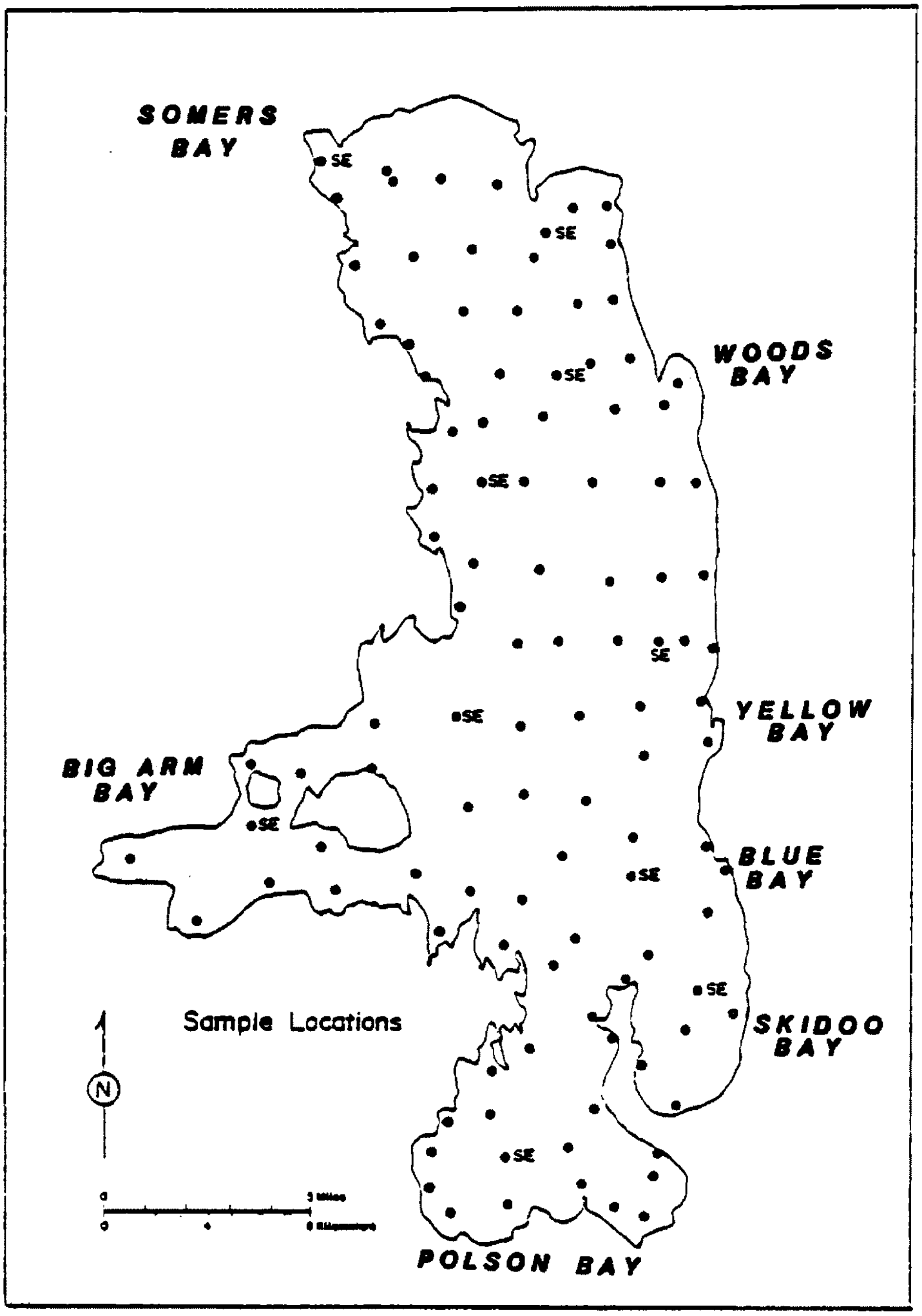

Fig. 2. Sample locations in Flathead Lake. Samples taken at sites marked SE were sequentially extracted (see text).

Sequential Extraction

A small number of the samples (Fig 2) were selected for a sequential extraction (Chester and Hughes, 1967; Gupta and Chen, 1975; and Forstner, 1981). The extraction scheme used in this study was a simple, two step extraction.

The first step was identical to the acetic acid extraction previously described. After the sample was centrifuged, the residue was washed and dried, and a 0.25 gm. subsample was taken. The subsample was fused with 1.25 gm. of sodium carbonate in a platinum crucible at 1100^{0} C for 15 minutes, and then dissolved with 5.0 ml. of concentrated nitric acid and deionized water. The resulting solution was then diluted to 50.0 ml. (Jeffery, 1975).

The second step of the extraction process removes residual metals that are more tightly bound to the sediment than the metals removed in the acetic acid extraction. These residual metals include metals bound in silicate lattices, coprecipitated in oxide phases that are not readily reducible, and metals that are tightly bound to organic materials. The metals bound in this fraction should not be available to the biota, under most conditions.

Analysis

Solutions were analyzed for Fe, Mn, Zn, and Cu using a Perkin--Elmer 5000 atomic absorption spectrophotometer in flame mode, using the standard analytical conditions for that machine (Perkin-Elmer, 1976). Reagent blanks were prepared and duplicates or spikes of every fifth sample were analyzed. Standard solutions were made up with compositions that duplicated those in the sample solutions. Reagent grade materials were used throughout.

Other Analyses

Besides the metals analysis, samples were analyzed for extractable and total phosphorus (both organic and inorganic), total carbon, nitrogen, hydrogen, and grain size, and for the mineralogy of the sand, silt, and clay size fractions. Statistical analysis of the data was performed using the SCSS software package (Nie et al., 1980).

RESULTS

Iron

Extractable Fe in the oxidized sediment layer has a mean of 3820 ppm (S.D.=1200, N=70). In the reduced layer the mean is 3430 ppm (S.D.=1530, N=110). Results of the sequential step extraction indicate that only a small percentage of the total Fe is extractable (Fig. 3). In the oxidized layer an average of 7.7% is extractable, and in the reduced layer, 7.3%.

The average total Fe in the sediment samples that were sequentially extracted (Fig. 3) is very close to the average recent lake sediment value (43,000 ppm), and to the global shale standard (46,700 ppm) (Forstner, 1981a, p. 136).

Contour maps of the distribution of extractable Fe data for oxidized and reduced layers show that the highest concentrations of extractable Fe occur in four different areas (Fig. 4). In two of these areas (northeast and southwest areas of Big Arm Bay) we found crusts of nodular Fe similar to those found by Cronan and Thomas (1972) in the Great Lakes, and to cases reported by Calvert and Price (1977). These crusts form a hard pavement at the sediment-water interface. A Peterson dredge with attached lead plates, weighing nearly sixty pounds, had difficulty penetrating the crust. The crusts appear to have a lateral extent of about 20 square meters. They grade into areas

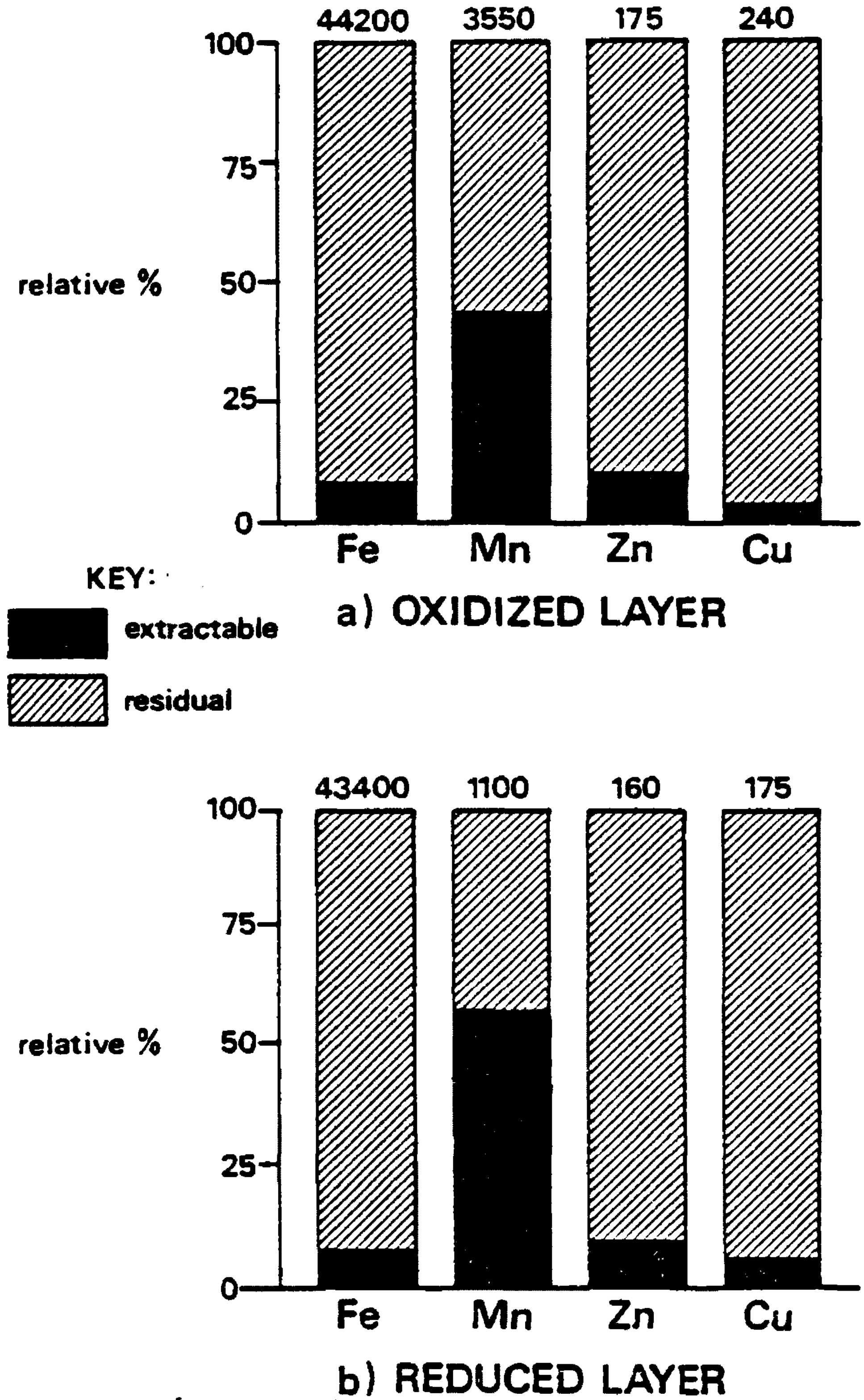

Fig. 3. Histogram depicting results of the sequential extractions for the oxidized and reduced layers. At the top of each bar, the average total amount of each metal is posted, in parts per million.

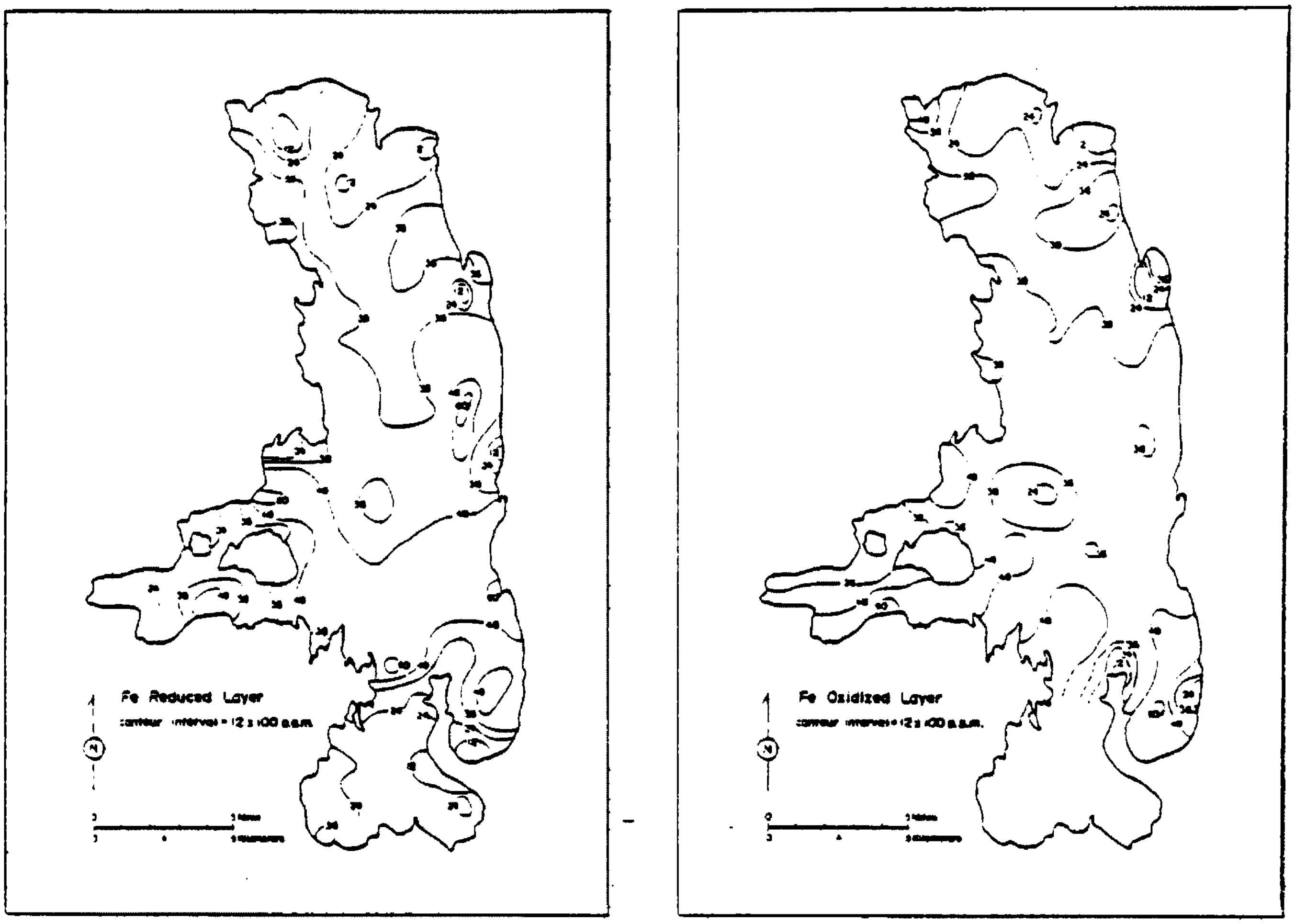

Fig. 4. Contour maps of the distribution of extractable Fe in the reduced (a) and oxidized (b) layers. Contour interval is 1200 ppm.

where smaller discontinuous nodules (down to sand size) are present. Pieces of the crust react violently when treated with hydrogen peroxide, indicating that they may be bound by an organic matrix.

In the other two areas where high Fe concentrations were found (in southeastern Big Arm Bay and the area along the southeast shoreline extending into Skidoo Bay) no Fe nodules or crusts have been located.

Manganese

Extractable Mn is enriched in the oxidized layer of the surface sediments (Fig. 5). The average Mn content of the oxidized layer is 1590 ppm (S.D.=1000), while that of the reduced layer is 810 ppm (S.D.=780). A more detailed comparison of the extractable Mn in the oxidized layer versus that in the reduced layer was made on 70 samples for which both oxidized and reduced subsamples were available. In these samples, 83% of the oxidized layers contain at least 10% more extractable Mn than the reduced layers (Fig. 6).

The sequential extraction shows that a much higher proportion of the total Mn is extractable, relative to Fe (Fig. 3). The mean for the oxidized layer is 43.5%, while in the reduced layer an average of 57.3% of the total Mn is extractable.

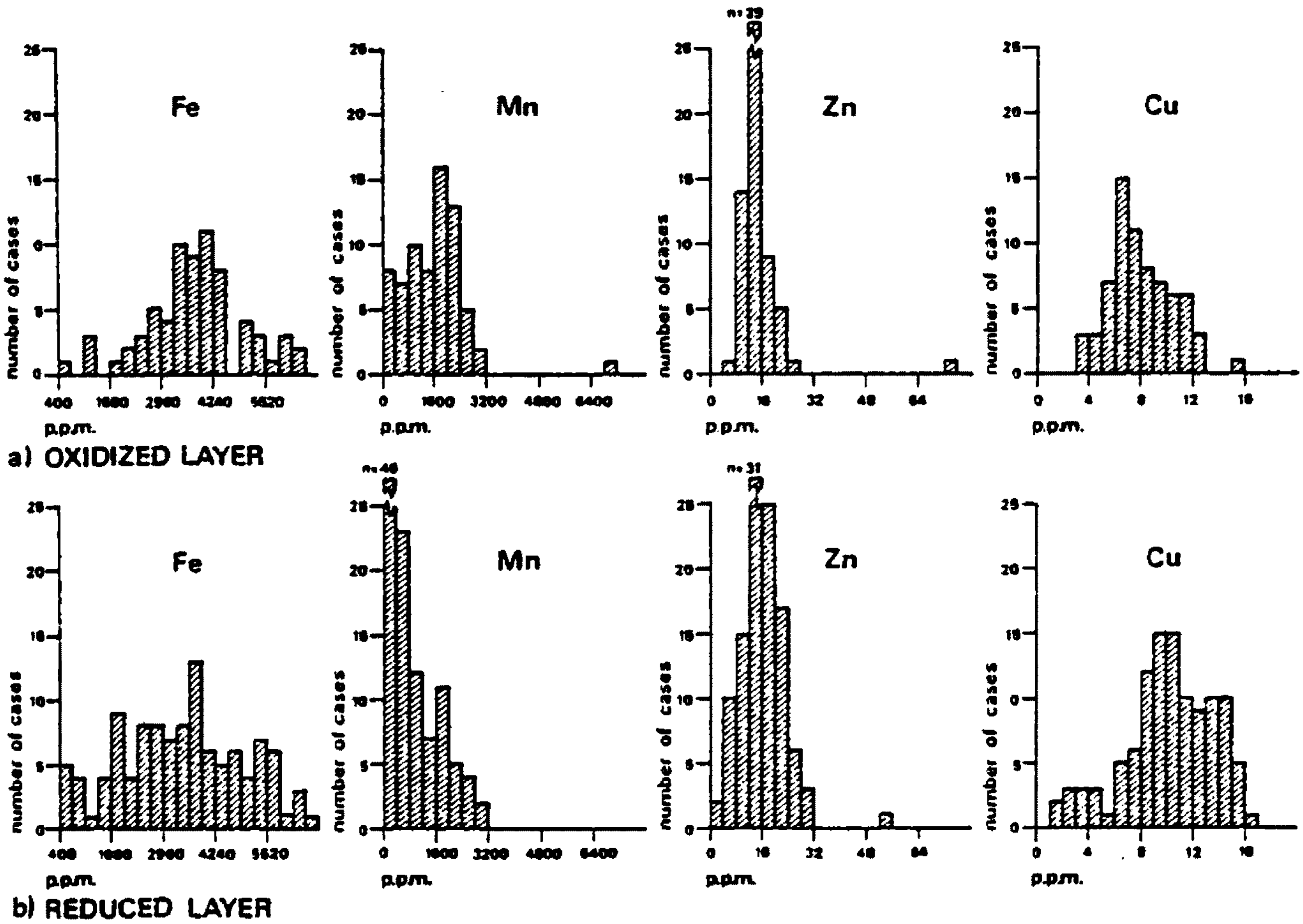

Fig. 5. Histograms of the acetic acid extractable metal concentrations in the oxidized and reduced sediment layers.

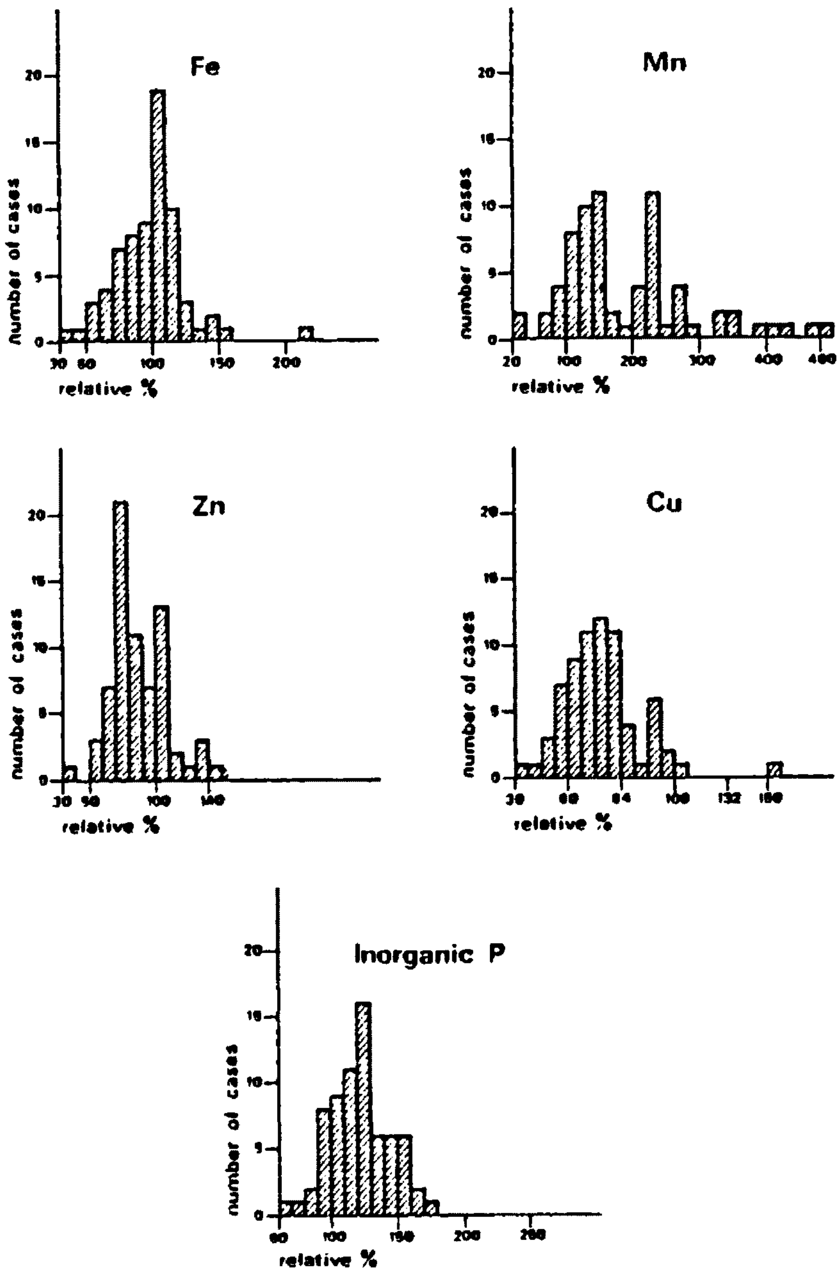

Fig. 6. Histograms portraying comparisons of the amount of extractable material in the oxidized layer to that in the reduced layer, where both subsamples were available at the same sampling site. The relative % was calculated as follows: (Concentration of extractable element in the oxidized layer divided by concentration of extractable element in the reduced layer) x 100%.

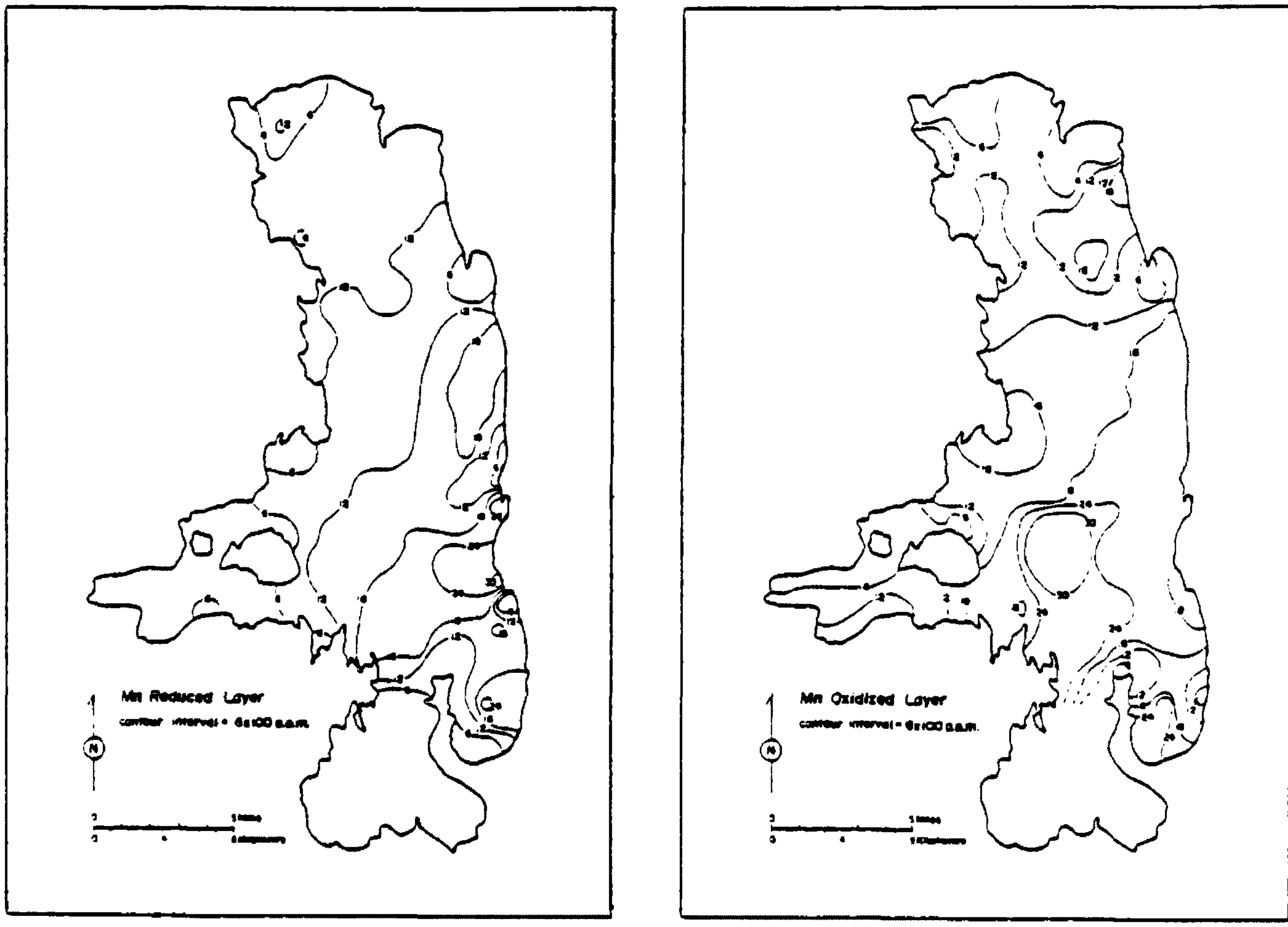

Fig. 7. Contour maps of the distribution of extractable Mn in the reduced (a) and oxidized (b) layers. Contour interval is 600 ppm.

Comparison of the total Mn measured in the sequential extractions (Fig. 3) with other recent lake sediments (Forstner, 1981a) indicates that Mn in Flathead Lake sediments exceeds both the average values (750 ppm) and the range (100-1800 ppm). Forstner (1981a) states, however, that Mn has a wider variation in values than most elements, due to its diagenetic mobility, so high values of Mn are not surprising.

Zinc

Extractable Zn in the oxidized layer averages 15.1 ppm (S.D.=7.7). In the reduced layer, the mean is 15.9 ppm (S.D.=6.9). A detailed comparison of oxidized and reduced layers from the same samples reveals a systematic enrichment of Zn in the reduced layer. 61.4% of the samples contain at least 10% less extractable Zn in the oxidized layer than in the reduced layer.

The extractable portion of the total Zn present was low (Fig. 3), averaging 10.1% in the oxidized layer, and 9.6% in the reduced layer. The total Zn recoverable in the sequential extraction fell within the range of 87 recent lake values reported by Forstner (1981a).

The area with the highest concentration of Zn is in Somers Bay (Fig. 8), where the concentrations of extractable Zn are 3-5 times higher than the average concentrations. Most of the other locations containing higher than average Zn values are also near developed sec-

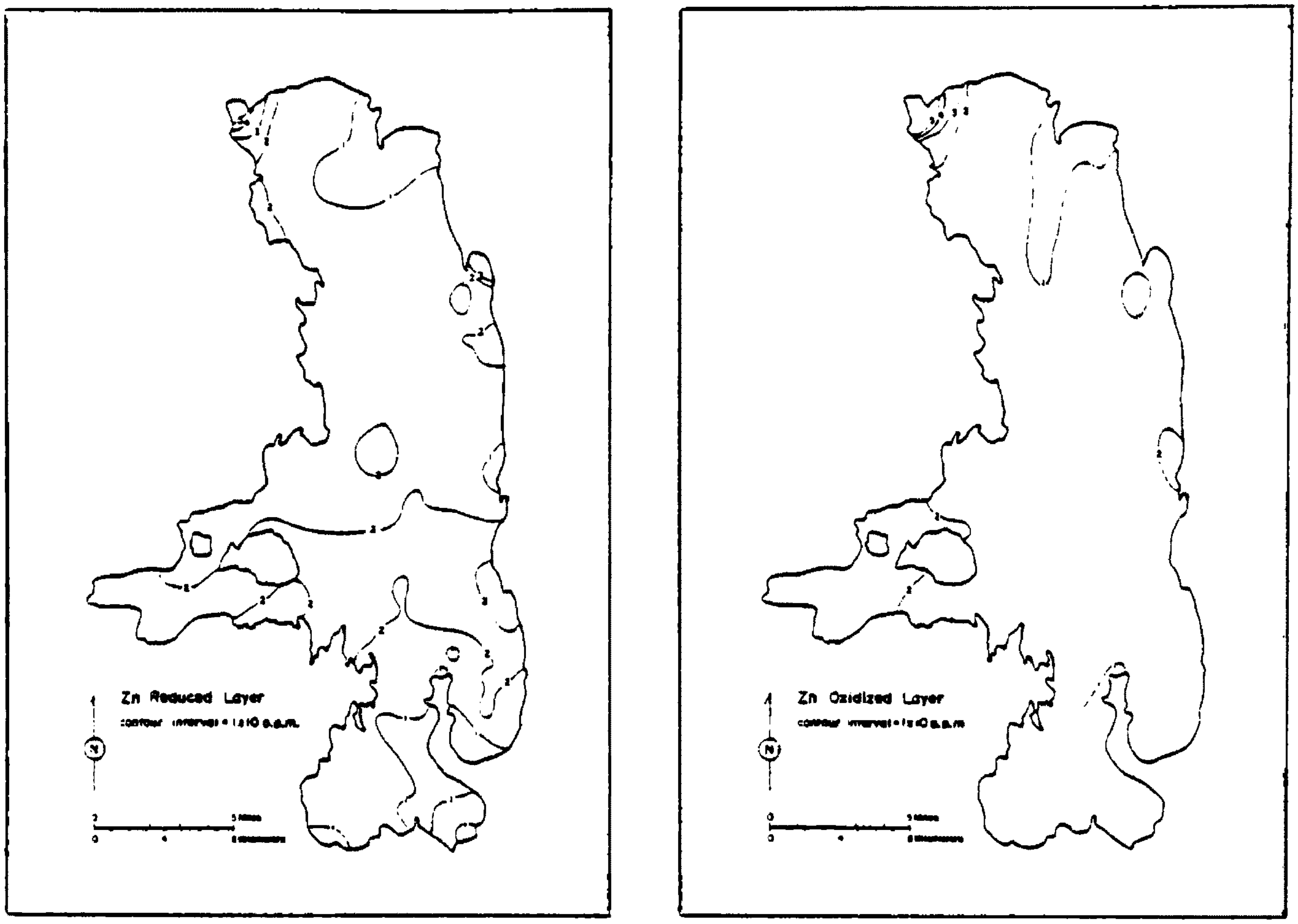

Fig. 8. Contour maps of the distribution of extractable Zn in the reduced (a) and oxidized (b) layers. Contour interval is 10 ppm.

tions of the shoreline. The exception is the deep southern area of the lake, west of Blue Bay, which also has higher than average Zn concentrations in the reduced layer.

Copper

Extractable Cu in the oxidized layer has a mean of 8.0 ppm (S.D.=3.4). Comparisions of oxidized and reduced layers from the same samples show that 84% of the reduced subsamples contain at least 10% more extractable Zn than the oxidized layer (Fig. 6).

In the sequential extraction, only 4.1% of the total Cu is extractable in the oxidized layer, and 5.8% in the reduced layer (Fig. 3). The total amount of Cu in the sediments is high relative to the mean and high values for 87 recent lakes (Forstner, 1981a), which clustered around a mean of 45 ppm. The total Cu in the samples from Flathead Lake averages 238.0 ppm in the oxidized layer, and ranges from a low of 85.4 to a high of 833.0 ppm. In the reduced layer, the mean is 176.0 ppm, with the total concentrations varying from 67.2 to 428.0 ppm.

The areal distribution of extractable Cu in the reduced layer closely mimics the distribution of Fe in the reduced layer (see Figs. 4a and 9a), but this close correlation is not found in the oxidized layer. However, two of the areas which have high Cu values in the reduced layer also have high values in the oxidized layer: the south-

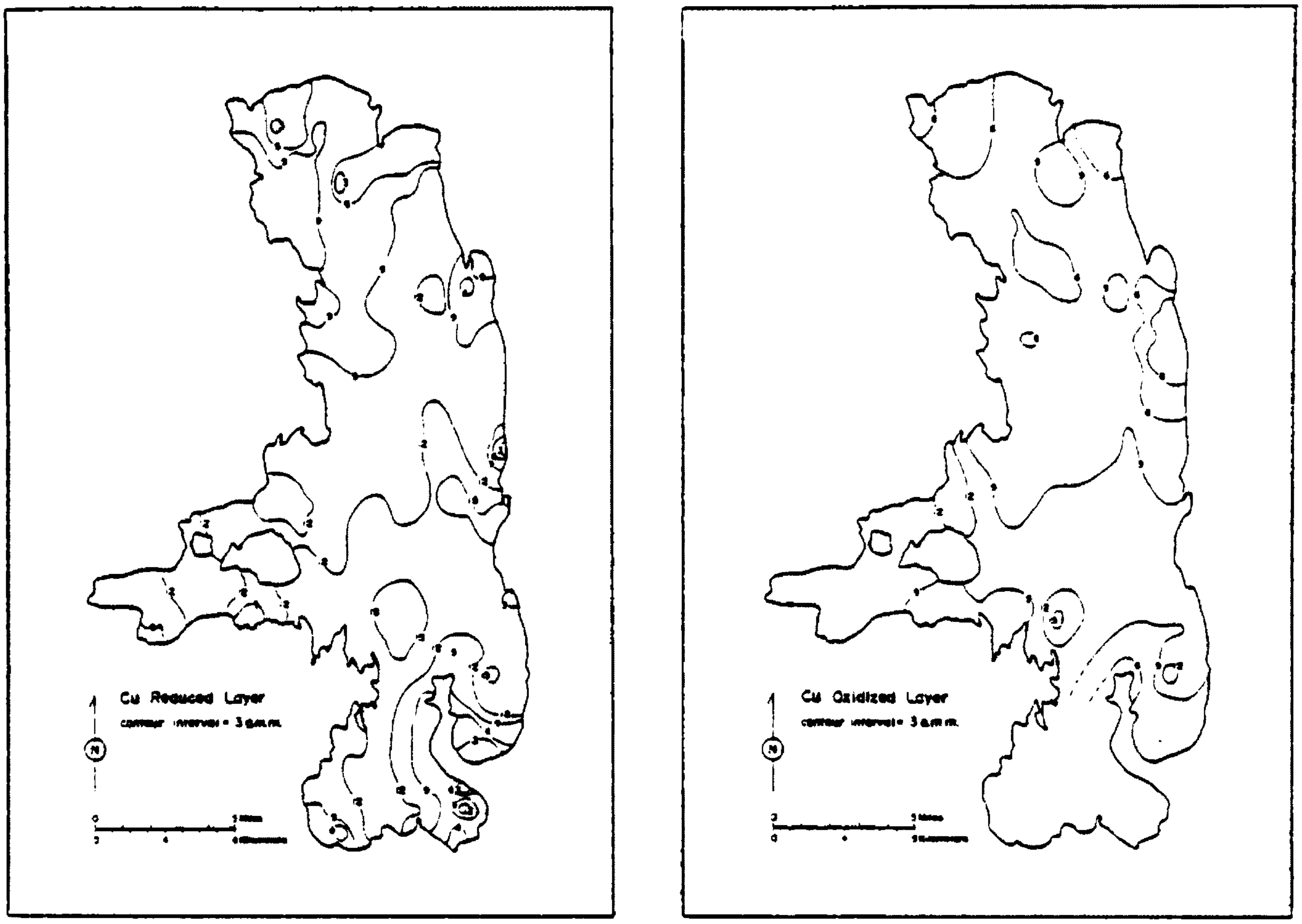

Fig. 9. Contour maps of the distribution of extractable Cu in the reduced (a) and oxidized layers. Contour interval is 3 ppm.

eastern area of Big Arm Bay, and the northeast part of Big Arm Bay, where the nodular Fe crusts were located.

DISCUSSION

Tables IIa and IIb show the correlation coefficients of the measured variables for the oxidized and reduced layers. Tables III and IV contain the multiple linear regression statistics for the oxidized and reduced layers.

Manganese Diagenesis

The distribution of extractable Mn in the oxidized layer correlates best with the distribution of extractable Fe (Table IIa), indicating that Fe oxides and hydroxides may adsorb and coprecipitate some of the extractable Mn. Probably some extractable Mn is also leached from discrete Mn oxides (Forstner, 1981b; Hem, 1981). In the reduced layer, the major factors correlating with the distribution of extractable Mn are extractable inorganic phosphorus and extractable Fe (Tables IIb and IV).

As previously mentioned, extractable Mn shows a distinct enrichment in the oxidized layer, averaging 90%. This suggests that Mn may be moving as the result of diagenetic processes in the sediment column, a phenomenon frequently cited in the literature (Lynn and Bonatti, 1965; Robbins and Callender, 1975; and Klinkhammer, 1980).

Klinkhammer (1980) mentions that the simplest way to oxidize Mn^{++} is by the reaction:

Sample	Layer	Ext. Fe	Res. Fe	Ext. Mn	Res. Mn	Ext. Zn	Res. Zn	Ext. Cu	Res. Cu
34	Red.	1040	27500	37.6	170	14.6	215	12.2	416
60	Ox.	1900	25100	115	172	15.5	208	5.8	283
60	Red.	1860	30300	54.4	173	10.2	246	9.8	123
75	Ox.	1610	36700	1060	493	7.6	214	3.4	82
75	Red.	4540	33900	932	328	8.4	148	8.2	139
86	Ox.	4540	34700	1370	4410	10.9	226	7.4	190
86	Red.	5030	31500	1600	359	14.3	268	11.8	98
94	Ox.	3400	49200	87.1	9280	9.3	226	4.2	829
94	Red.	4590	52000	1690	486	17.3	108	9.4	348
123	Ox.	4540	46800	2080	3380	10.0	62.1	11.0	78
123	Red.	2790	47600	1960	624	10.7	110	7.4	110
136	Ox.	3200	54000	1040	1680	8.0	131	5.0	145
136	Red.	3400	46400	683	298	14.1	85.0	8.2	59
145	Ox.	3690	41900	1900	677	8.7	102	6.2	167
145	Red.	3570	60800	679	323	8.8	113	7.8	120
154	Red.	1330	35100	111	168	2.0	65.5	1.8	129
160	Ox.	4060	38300	442	242	54.7	105	3.0	84
160	Red.	3240	37500	148	182	42.6	106	4.6	142

Table I. Results of the sequential extractions, in ppm. Results given for oxidized and reduced subsamples, where available. Two figures given for each element - extractable and residual. Extractable Zn, e.g., was leached from the sediment sample by 20% acetic acid. Residual Zn was only released from the sediment by complete dissolution.

Mn	-.051							
Fe	.294	.514						
Cu	.119	.347	.406					
Inor. P	-.032	.409	.652	.406				
Carbon	.546	-.107	.359	.308	.359			
Sand	.018	-.250	-.234	-.233	-.265	.050		
Silt	-.499	-.182	-.256	-.402	-.167	.094	-.274	
Clay	.414	.356	.407	.532	.355	-.094	-.563	-.640
	Zn	Mn	Fe	Cu	Inor.P	Carbon	Sand	Silt

a) Oxidized layer

Mn	.327							
Fe	.531	.743						
Cu	.465	.525	.696					
Inor. P	.377	.771	.738	.396				
Carbon	-.029	-.350	-.280	.038	-.417			
Sand	-.526	-.345	-.650	-.712	-.376	.218		
Silt	-.098	-.395	-.227	.089	-.285	.581	-.355	
Clay	.580	.641	.807	.637	.586	-.293	-.702	-.413
	Zn	Mn	Fe	Cu	Inor.P	Carbon	Sand	Silt

b) Reduced layer

Table II. Correlation coefficients between measured parameters in the oxidized (a) and reduced (b) layers.

$$Mn^{++} + \frac{1}{2} O_2 = MnO_2 + 2H^+$$

However, he states that there is the possibility, shown by Morgan (1967) and Klinkhammer and Bender (1980), that hausmannite (Mn_3O_4), a less oxidized Mn(III) phase, actually forms during oxidation and precipitation. This suggestion has recently been corroborated by Hem (1981), who determined experimentally that, at temperatures between 0.5^{o} C. and 37.4^{o} C., oxidation of Mn^{++} leads to the formation of mixtures of hausmannite and feitknechtite by the following reactions:

$$3Mn^{++} + \frac{1}{2} O_2 + 3 H_2O = Mn_3O_4 + 6H^+ \text{ (hausmannite)}$$

$$2Mn^{++} + \frac{1}{2} O_2 + 3H_2O = 2MnOOH + 4H^+ \text{ (feitknechtite)}$$

With aging and further oxidation the hausmannite and feitknechtite may recrystallize to various forms of MnO_2, including birnessite and todorokite (Klinkhammer, 1980).

Below the oxidized zone is a neutral zone, in which Mn compounds are neither dissolved nor precipitated. In this zone, Mn^{++} moves by diffusion (Robbins and Callender, 1975). A zone of dissolution underlies the neutral zone. In that zone, the Mn oxides and hydroxides formed at the sediment-water interface dissolve by oxidation-reduction reactions (Robbins and Callender, 1975). The metabolic reactions of bacteria probably control the reduction of Mn compounds by the generalized reaction (Berner, 1980):

```
DEPENDENT: FEEX 2 VARIABLES IN. LAST IN: CLAY

MULTIPLE R =       .56720   R SQUARE =      .32172    R SQUARE CHG =  .05765
F CHG =           1.10497   SIGNIF F CHG = .31233    F =            3.08302
SIGNIF F =         .08020

IN EQUATION
   VARIABLE             B      BETA        F    SIGF    CORR    PART    PRTL
   MNEX            .51038    .42237    2.986    .108    .514    .395    .432
*  CLAY          23.46219    .25695    1.105    .312    .407    .240    .280
  (CONSTANT)   1603.90607              1.579    .231

DEPENDENT: CUEX 2 VARIABLES IN. LAST IN: FEEX

MULTIPLE R =       .60250   R SQUARE =      .36301    R SQUARE CHG =  .08041
F CHG =           1.64096   SIGNIF F CHG = .22257    F =            3.70425
SIGNIF F =         .05332

IN EQUATION
   VARIABLE             B      BETA        F    SIGF    CORR    PART    PRTL
   CLAY            .07552    .40512    2.794    .119    .532    .370    .421
*  FEEX         6.339-04    .31049    1.641    .223    .476    .284    .335
  (CONSTANT)      1.02901               .151    .704
```

Table III. Results of multiple linear regression analysis for the oxidized layer. FEEX stands for extractable Fe, INPEX for extractable inorganic phosphorus, etc.

DEPENDENT: FEEX 2 VARIABLES IN. LAST IN: INPEX

MULTIPLE R =	.87059	R SQUARE =	.75792	R SQUARE CHG =	.10733
F CHG =	19.50910	SIGNIF F CHG =	.00006	F =	68.38006
SIGNIF F =	.00000				

IN EQUATION

VARIABLE	B	BETA	F	SIGF	CORR	PART	PRTL
CLAY	34.43183	.56939	38.662	.000	.807	.461	.684
*INPEX	1.17435	.40447	19.509	.000	.738	.328	.554
(CONSTANT)	87.59280		.069	.793			

DEPENDENT: MNEX 2 VARIABLES IN. LAST IN: FEEX

MULTIPLE R =	.81301	R SQUARE =	.66098	R SQUARE CHG =	.06635
F CHG =	8.61109	SIGNIF F CHG =	.00529	F =	42.89253
SIGNIF F =	.00000				

IN EQUATION

VARIABLE	B	BETA	F	SIGF	CORR	PART	PRTL
INPEX	.72527	.48909	14.119	.001	.771	.330	.493
*FEEX	.19508	.38195	8.611	.005	.743	.258	.405
(CONSTANT)	−905.27896		20.332	.000			

DEPENDENT: CUEX 3 VARIABLES IN. LAST IN: CLAY

MULTIPLE R =	.78224	R SQUARE =	.61190	R SQUARE CHG =	.06242
F CHG =	6.91572	SIGNIF F CHG =	.01181	F =	22.59891
SIGNIF F =	.00000				

IN EQUATION

VARIABLE	B	BETA	F	SIGF	CORR	PART	PRTL
*FEEX	9.223−04	.40908	6.227	.016	.696	.237	.356
SILT	.06623	.37235	12.252	.001	.089	.333	.471
CLAY	.06284	.46093	6.916	.012	.637	.250	.372
(CONSTANT)	1.38940		1.217	.276			

DEPENDENT: INPEX 2 VARIABLES IN. LAST IN: FEEX

MULTIPLE R =	.80975	R SQUARE =	.65570	R SQUARE CHG =	.06107
F CHG =	7.80409	SIGNIF F CHG =	.00769	F =	41.89714
SIGNIF F =	.00000				

IN EQUATION

VARIABLE	B	BETA	F	SIGF	CORR	PART	PRTL
MNEX	.33496	.49671	14.119	.001	.771	.332	.493
*FEEX	.12719	.36928	7.804	.008	.738	.247	.388
(CONSTANT)	734.31666		36.037	.000			

Table IV. Results of multiple linear regression analysis for the reduced layer.

$$CH_2O + 2MnO_2 + 3CO_2 = 2Mn^{++} + 4HCO_3^-$$

Below the zone of dissolution Mn^{++} equilibrates with authigenic Mn phases (Robbins and Callender, 1975). According to Berner (1980), the most common reduced phase is rhodochrosite ($MnCO_3$), but other possible phases include reddingite [$Mn_3(PO_4)_2*3H_2O$], and several forms of Mn sulfide.

The reduced sediment layer of Flathead Lake may contain some rhodochrosite, but in view of the small amount of carbonate in the sediment (Decker, 1968) the amount of rhodochrosite is probably low. The Mn phosphate reddingite may form a more important reduced Mn phase, based on the high concentrations of extractable phosphorus, which suggest that phosphates may be stable. Statistical analysis of the data for the reduced layer indicates that extractable inorganic phosphorus correlates with both extractable Mn and extractable Fe (Table IIb). An examination of the partial correlation coefficients seems to show that the correlation of extractable Mn and phosphorus remains independent of the correlation of extractable Fe and phosphorus (Table V). The presence of a second phase containing Mn and phosphorus probably causes the correlation of extractable Mn and phosphorus, which may be the Mn phosphate, reddingite.

One difficulty in this, and other studies, has been the identification of postulated mineral species (Emerson and Widmer, 1978; Klink-

First Order Partials
Control: Fe

Mn	-.119						
Cu	.156	.016					
Inor. P	-.026	.493	-.245				
Carbon	.147	-.222	.338	-.325			
Sand	-.281	.271	-.476	.203	-.549		
Silt	.028	-.348	.354	-.179	.553	-.679	
Clay	.303	.104	.178	-.023	-.119	-.395	-.399
	Zn	Mn	Cu	Inor.P	Carbon	Sand	Silt

First Order Partials
Control: Mn

Fe	.455						
Cu	.364	.537					
Inor. P	.208	.388	-.017				
Carbon	.097	-.031	.279	-.246			
Sand	-.466	-.627	-.665	-.184	-.386		
Silt	.037	.109	.380	.514	-.570		
Clay	.511	.643	.460	.189	-.096	-.667	-.226
	Zn	Fe	Cu	Inor.P	Carbon	Sand	Silt

First Order Partials
Control: Clay

Mn	-.071						
Fe	.131	.499					
Cu	.151	.198	.400				
Inor. P	.056	.636	.554	.035			
Carbon	.182	-.222	-.076	.305	-.316		
Sand	-.205	.191	-.200	-.483	.062	-.623	
Silt	.191	-.187	.197	.502	-.058	.528	-.993
	Zn	Mn	Fe	Cu	Inor.P	Carbon	Sand

Table V. First-order partial correlation coefficients for the reduced layer.

hammer, 1975), particularly by x-ray diffraction methods. One reason for this difficulty is the relatively low volumetric importance of the phases being sought, which makes them difficult to separate and concentrate. Also, since x-ray diffraction cannot identify amorphous phases, the amorphous nature of many authigenic compounds may constitute the most important reason for the difficulty encountered in identification of these authigenic minerals (Emerson and Widmer, 1978).

Iron and Phosphorus Diagenesis

Extractable Mn content and the percent clay size fraction correlate best with the distribution of extractable Fe in the oxidized layer (Tables IIa and III). The extractable Fe probably exists in three forms: as hematite; adsorbed and coprecipitated by the Mn oxides mentioned above; and adsorbed by clay minerals. Hematite occurs in the surface sediments of Flathead Lake as films that coat clay grains and other minerals, and as discrete grains (Decker, 1968). Mn oxides readily adsorb and/or coprecipitate Fe, because of the chemical similarity between Fe and Mn (Krauskopf, 1979). Clay minerals efficiently adsorb Fe, especially in the form of $Fe(OH)_3$ colloids (Forstner, 1981b). Extractable inorganic phosphorus in the oxidized layer correlates with extractable Fe, and to a lesser extent, with extractable Mn (Tables IIa and III). Fe and Mn oxides and hydroxides efficiently adsorb aqueous phosphorus (Wetzel, 1975). Multiple linear regression and partial correlation coefficients revealed no appreciable correlation of inorganic phosphorus with grain size, independent of Fe and Mn content (Tables III and V). This may indicate that the Fe and Mn oxides adsorb phosphorus so efficiently that adsorption by clay minerals plays a minor role in controlling the distribution of phosphorus.

In the reduced layer, grain size and extractable inorganic phosphorus correlate with the distribution of extractable Fe (Tables IIb and IV). As indicated above in the section on Mn diagenesis, both extractable Mn and extractable Fe correlate with the distribution of inorganic phosphorus, seemingly independent of one another.

A diagenetic model for the behavior of extractable Fe proposed for Flathead Lake is similar to the model proposed for Mn diagenesis. The apparent immobility of Fe in the surface sediments (Figs. 5 and 6) constitutes the major difference between the two models. Krauskopf (1979) and Mortimer (1971) have previously dealt with sediment systems undergoing oxidation-reduction and found that Mn often becomes mobile before Fe, because of Mn's greater sensitivity to changes in redox conditions. Inorganic phosphorus may be mobile in the sediments, since the oxidized layer does contain an average of 23% more extractable phosphorus than the reduced layer, with 54% of the samples having an enrichment of more than 10% in the oxidized layer (Figs. 6 and 10). In view of the agricultural activity and increased population in the Kalispell valley, input of cultural phosphorus probably occurs, which may enhance the enrichment of phosphorus in the oxidized layer.

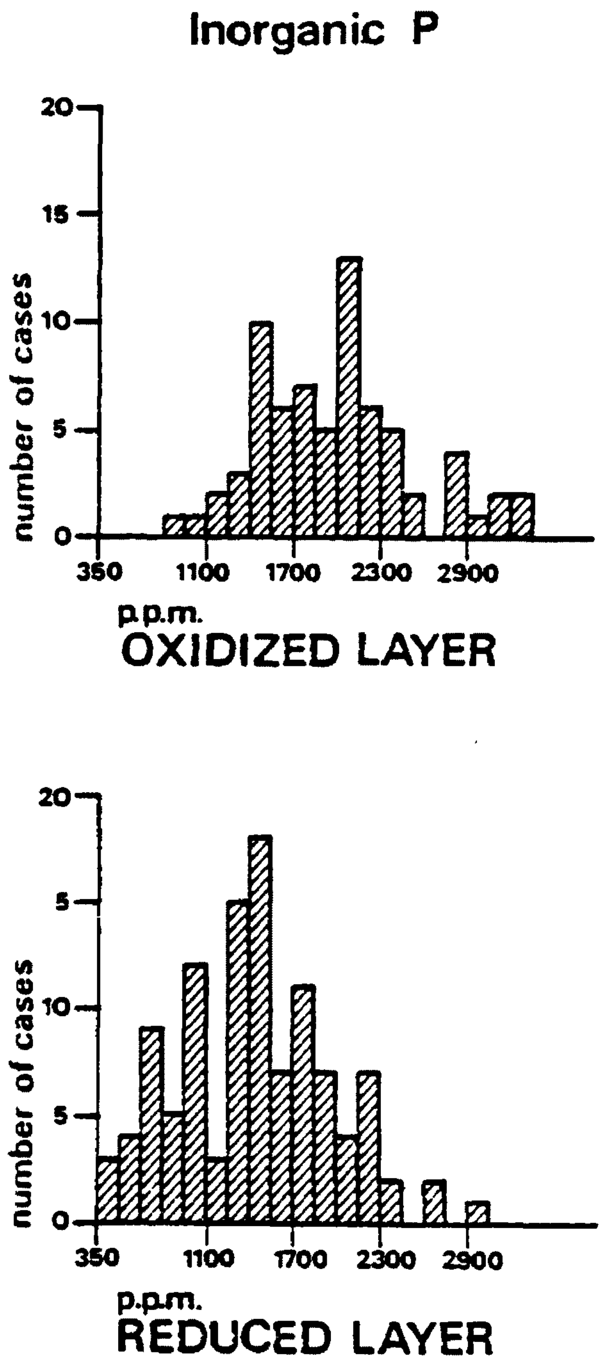

Fig. 10. Histograms of the extractable inorganic phosphorus in the oxidized and reduced sediment layers.

A possible diagenetic model for explaining the distribution of extractable Fe in the sediments of Flathead Lake involves the burial of initially oxidized sediments containing hematite and ferric hydroxides, together with adsorbed inorganic phosphorus. Decomposition of organic matter by bacteria causes the sediments to become reducing. After the bacteria have utilized other, more energy efficient oxidants, such as oxygen, nitrate, and Mn oxides (Berner, 1980), the reduction of Fe begins. The metabolic reactions are of the form (Berner, 1980):

$$4Fe(OH)_3 + CH_2O + 7CO_2 = 4Fe^{++} + 8HCO_3^- + 3H_2O$$

This reaction would release Fe^{++} and phosphorus into the pore water. Eventually, as the activity of Fe^{++} increased, the ion activity product would exceed the solubility product of one of the reduced authigenic Fe minerals, and precipitation would ensue. Based on the low sulfate content of fresh water, the small amount of organic material and carbonate in the sediments of Flathead Lake, and the large amounts of extractable inorganic phosphorus present, the Fe phase that precipitates probably consists of an Fe phosphate, vivianite ($Fe_3(PO_4)_2$*-$8H_2O$). Small nodules of vivianite which have been discovered in two previous studies of Flathead Lake sediments (Joyce, 1980; Potter, 1978) support this hypothesis. Emerson and Widmer (1978) in a study of the Greifensee, a Swiss lake, reported similar results.

Geochemical Classification of Flathead Lake Sediments

Recently, Berner (1981) proposed a geochemical classification of sediments based on the concentrations of O_2, H_2S, and more importantly, on the identification of the Mn and Fe mineral phases that are present. Based on the Fe minerals that are known to be present, hematite and vivianite, on the suspected presence of Mn oxides, hydroxides, and phosphates, and, especially, on the lack of any sulfide minerals, the sediments in Flathead Lake appear to fit into the non--sulfidic continuum of Berner's (1981) classification scheme.

Specifically, this involves the presence of an oxic layer, demonstrated by the presence of hematite, and the assumed presence of Mn oxides. Below this oxic layer, the sediments enter the post-oxic (non--sulfidic) phase, identified by the presence of vivianite, and the assumed presence of reddingite and other reduced Mn phases, and by the lack of sulfide minerals. Because of the small amount of organic matter deposited in the sediments and the presence of a year round oxidizing environment at the sediment water interface, only a small amount of decomposable organic matter is present in the sediments upon burial. The lack of sufficient organic matter probably prevents the sediments from attaining the strongly reducing conditions necessary for the formation of the methanic phase, Berner's (1981) designation for the most reducing non-sulfidic environment.

Sources of Zinc

The distribution of Zn in the oxidized layer correlates with the amount of carbon present and with grain size (Table IIa). In the reduced layer, the major correlation is with grain size (Table IIb). Partial correlation coefficients and multiple linear regression statistics indicate that the correlation of Zn with Fe in the reduced layer (Tables IV and V) results from the correlation of Zn with clay size fraction and of Fe with clay size fraction, and that no direct link between extractable Zn and extractable Fe actually exists. The lack of correlation between carbon and Zn in the reduced layer probably arises because of the destruction of organic matter by microorganisms.

Another factor that seems to control the distribution of extractable Zn in the sediments is geographic location. As shown in Fig. 8, the highest Zn values are found in Somers Bay, in both the oxidized and reduced layers. This location has extractable Zn that is 3-5 times higher than average extractable concentrations. In addition, the amount of extractable Zn as a percent of total Zn is 2 times higher than the mean, indicating that more of the Zn in that location is readily available in aqueous form.

The high amount of Zn near a populated area suggests cultural input of Zn to the lake sediments. The long history of industrial activity in Somers, as well as its continuation as a population center for over 80 years, lend support to that idea. Over the years, Somers has had a steamship port, a sawmill, a mill pond, scrap metal yards, a railroad tie factory, a tannery, and other industry. In Somers, as in most small towns, septic systems dispose of household sewage. Domestic effluents are a common source of Zn in aquatic systems (Wittmann, 1981). A study by Konizeski and others (1968), found that during the months of August through March, when the water level of Flathead Lake is lowered, ground water flows through the sandy floodplain aquifer of the Flathead River directly beneath the town of Somers and into Flathead Lake. This ground water flow may transport Zn into the lake, and ultimately, into the sediments in Somers Bay.

The majority of the other areas that show high extractable Zn values also occur near populated sections of the shoreline. The possibility that ground water flow from communities surrounding the lake contributes Zn to the lake, together with the fact that some of the areas of highest extractable Fe and Cu concentrations are near the shoreline, all point to the need for greater study of the groundwater and sediment porewater chemistry.

The southern portion of the lake comprises the main area of high Zn concentrations not located near the shoreline (Fig. 8). This area also tends to have high percentages of clay size material, because of the great distance from the Flathead River delta. The Flathead River contributes most of the sediment to Flathead Lake. Considering the good correlation of extractable Zn with the clay size fraction (Table II), higher than average values of Zn in this area are not surprising.

Sources of Copper

Grain size, and to a lesser extent, extractable Fe, correlate with the distribution of extractable Cu in the oxidized layer (Table

IIa). In the oxidized layer, clay minerals probably adsorb Cu, while Fe oxides and hydroxides both adsorb and coprecipitate it (Forstner, 1981b). Examination of the correlation coefficients and of the multiple linear regression statistics for the reduced layer (Tables IIb and IV) indicates that extractable Fe and grain size correlate with the distribution of extractable Cu. Comparison of the contour maps of Fe and Cu in the reduced layer also shows the correlation between the two elements (Figs. 4a and 9a). However, while Cu correlates with percent clay in the reduced layer (Table IIb), multiple linear regression reveals that extractable Cu also correlates with percent silt (Table IV). This is the only case where a positive correlation of any of the extractable metals appears with coarser grained sediments. As a general rule, extractable metals usually correlate with finer grained sediments, because of surface area effects (Forstner, 1981b).

The positive correlation of extractable Cu with the silt size fraction in the reduced layer, taken together with the extremely high values of total Cu, almost all of which resides in the residual fraction, suggests two sources for the extractable Cu. One source consists of Cu bound loosely by extractable Fe compounds and by clay minerals. The other source consists of detrital Cu minerals.

The presence of detrital Cu minerals would explain the high concentrations of residual Cu in the sediments. Because it is tightly bound to the sediment, the large amounts of Cu should not be available to the biota, under normal conditions. Any detrital Cu minerals present in the sediment have presumably been altered from their original sulfide mineralogy, due to weathering at the outcrop, during transport, and in the oxidized layer of the sediments. Possible Cu phases now present may include tenorite, cuprite, malachite, and azurite.

Rocks of the Belt Supergroup are a likely source for detrital Cu minerals. They contain ore-grade Cu mineralization, with Cu contents varying from background levels of 20 ppm to highs of at least 20,000 ppm (Harrison, 1972; Harrison and Grimes, 1970). Cu minerals include chalcopyrite, chalcocite, digenite, bornite, and covellite (Harrison, 1972). Several types of Cu deposits are known, and are found in almost every stratigraphic unit, and every geographic area of the Belt basin (Harrison, 1972). Mineral companies are actively exploring the Belt basin for these Cu deposits. Besides Cu, the deposits also provide sources of Pb, Ag, and Hb (Clark, 1971; Lange and Moore, 1981).

Remobilization of Extractable Material

The concentrations of extractable metals and nutrients measured in the surface sediments exceed the levels in the waters of Flathead Lake by at least an order of magnitude (Stuart and Stanford, 1981). This reservoir of extractable material may be released if the chemical environment of the sediments changes sufficiently. The release of phosphorus to the lake waters would be particularly important because of the role of phosphorus as the limiting nutrient in the Flathead Lake ecosystem (Stuart and Stanford, 1981).

The distribution of extractable Zn indicates that some pollution of the lake may be occurring near populated areas. Stanford (personal comm., 1982) recently discovered higher levels of primary productivity in the waters of some of the bays with populated shorelines, which tends to support that idea. Increased pollution levels could lead to a situation in which the bottom waters of Flathead Lake are no longer oxidizing. If that occurred, the sediments of Flathead Lake might become a source of both nutrients and metals (Wetzel, 1975; Leland et al., 1973), which would tend to aggravate any developing pollution problem. The high economic, recreational, and ecological value placed on the lake by its many users suggest the need for continued monitoring of the waters and sediments of Flathead Lake.

REFERENCES

Berner R.A. (1981) A new geochemical classification of sedimentary environments. J. Sed. Petrol. 51, 359-365.

Berner R.A. (1980) Early Diagenesis: A Theoretical Approach, 241 pp., Princeton Univ. Press.

Calvert S.E. and Price N.B. (1977) Shallow water, continental margin and lacustrine nodules: Distribution and geochemistry. In Marine Manganese Deposits (ed. G.P. Glasby), pp. 45-86. Elsevier.

Chester R. and Hughes M.J. (1967) A chemical technique for the separation of ferro-manganese minerals, carbonate minerals, and adsorbed trace elements from pelagic sediments. Chem. Geol. 2, 249-262.

Clark A.L. (1971) Stratabound copper sulfides in the Precambrian Belt Supergroup, northern Idaho and northwestern Montana, U.S.A. Soc. Mining Geologists of Japan Spec. Issue 3, 261-267.

Crecelius E.A., Bothner M.H. and Carpenter R. (1975) Geochemistries of arsenic, antimony, mercury and related elements in sediments of Puget Sound, Environ. Sci. Technol. 9, 325-333.

Cronan D.S. and Thomas R.L. (1972) Geochemistry of ferromanganese oxide concretions and associated deposits in Lake Ontario. Geol. Soc. Am. Bull. 83, 1493-1502.

Decker G.L. (1968) Preliminary report on the geology, geochemistry, and sedimentology of Flathead Lake, northwestern Montana. M.S. Thesis, Univ. of Montana, 91 pp.

Emerson S. and Widmer G. (1978) Early diagenesis in anaerobic lake sediments - II. Thermodynamic and kinetic factors controlling the formation of iron phosphate. Geochim. Cosmochim. Acta 42, 1307-1316.

Forstner U. (1981a) Metal pollution assessment from sediment analysis. In Metal Pollution in the Aquatic Environment (eds. U. Forstner and G. Wittman), pp. 110-196. Springer-Verlag.

Forstner U. (1981b) Metal transfer between solid and aqueous phases. In Metal Pollution in the Aquatic Environment (eds. U. Forstner and G. Wittman), pp. 197-270. Springer-Verlag.

Goldberg E.D., Hodge V.F., Griffin J.J., Koide M. and Edgington D.N. (1981) Impact of fossil fuel combustion on the sediments of Lake Michigan. Environ. Sci. Technol. 15, 466-471.

Gupta S.K. and Chen K.Y. (1975) Partitioning of trace metals in selective chemical fractions of nearshore sediments. Environ. Letters 10, 129-158.

Harrison J.E. (1972) Precambrian Belt basin of northwestern United States: Its geometry, sedimentation, and copper occurrences. Geol. Soc. Am. Bull. 83, 1215-1240.

Harrison J.E. and Grimes D.J. (1970) Mineralogy and geochemistry of some Belt rocks, Montana and Idaho. U.S. Geol. Surv. Bull. 1312-O.

Hem J.D. (1981) Rates of manganese oxidation in aqueous systems. Geochim. Cosmochim. Acta 44, 1311-1317.

Jeffery P.G. (1975) Chemical Methods of Rock Analysis, 2nd ed., 526 pp., Pergamon Press.

Joyce M.J. (1980) Stratigraphy, clay mineralogy and pesticide analysis of Flathead Lake sediments, Flathead Lake, Montana. M.S. Thesis, Univ. of Montana, 86 pp.

Klinkhammer G.P. (1980) Early diagenesis in sediments from the eastern equatorial Pacific. II. Pore water metal results. Earth Planet. Sci. Lett. 49, 81-101.

Klinkhammer G.P. and Bender M.L. (1980) The distribution of manganese in the Pacific Ocean. Earth Planet. Sci. Lett. 46, 361-384.

Konizeski R.L., Brietkrietz A. and McMurtrey R.G. (1968) Geology and ground water resources of the Kalispell Valley, northwestern Montana. Montana Bur. Mines and Geol. Bull. 68, 42 pp.

Krauskopf K.B. (1979) Introduction to Geochemistry, 2nd ed., 617 pp., McGraw-Hill.

Lange I.M. and Moore J.N. (1981) A Cu-Ag bearing oolite bed in the Spokane Formation, Belt Supergroup near Wolf Creek, Montana. Geol. Soc. Am. Abstracts with Programs 13, 202.

Lynn D.C. and Bonatti E. (1965) Mobility of manganese in diagenesis of deep-sea sediments. Mar. Geol. 3, 457-474.

Michard G. (1971) Theoretical model for manganese distribution in calcareous sediment cores. J. Geophys. Res. 76, 2179-2186.

Morgan J.J. (1967) Chemical equilibrium and kinetic properties of manganese in natural waters. In Principles and Application of Water Chemistry (eds. S.D. Faust and J.V. Hunter), pp. 561-524. Wiley.

Mortimer C.H. (1971) Chemical exchanges between sediments and water in the Great Lakes - Speculations on probable regulatory mechanisms. Limnol. Oceanog. 16, 387-405.

Nie H.H., Hull C.H., Franklin M.N., Jenkins J.G., Sours K.J., Norusis M.J. and Beadle V. (1980) SCSS: A User's Guide to the SCSS Conversational System, 595 pp., McGraw-Hill.

Perkin-Elmer Corp. (1976) Standard Methods - Atomic Absorption Spectrophotometer Manual.

Potter D.S. (1978) The zooplankton of Flathead Lake: A historical review with suggestions for continuing lake resource management. Ph.D. Thesis, Univ. of Montana.

Price N.B. (1976) Chemical diagenesis of sediments. In Chemical Oceanography (eds. J.P. Riley and R. Chester) Vol. 6, pp. 1-58. Academic Press.

Robbins J.A. and Callender E. (1975) Diagenesis of manganese in Lake Michigan sediments. Am. J. Sci. 275, 512-533.

Skei J. and Paus P.E. (1979) Surface metal enrichment and partitioning of metals in a dated sediment core from a Norwegian fjord. Geochim. Cosmochim. Acta 43, 239-246.

Stuart T. and Stanford J. (1981) Annual Report - Flathead Lake Ecosystem. Yellow Bay Biological Station.

Wittman G. (1981) Toxic metals. In Metal Pollution in the Aquatic Environment (eds. U. Forstner and G. Wittman) pp. 3-70. Springer--Verlag.

APPENDIX

Raw data file for the Flathead Lake Study. There are four records per sample.

Key:

	Column A	B	C	D	E	F	G	H
Record 1	Record No.	Year	Sample no.	N.A.	1=Oxidized 2=Reduced	Water depth at site	Latitude	Longitude
Record 2	Record no.	Ext. Zn	Ext. Mn	Ext. organic phosphorus	Ext. inorganic phosphorus	Ext. Fe	Ext. total phosphorus	
Record 3	Record no.	Total K	Total Na	Total Mn	Total Fe	Total Al	Ext. Cu	
Record 4	Record no.	Total N	Total C	Total H	% Sand	% Silt	% Clay	

A value of 9999.00 for any variable indicates that it was not measured.

11	80 1 1 2	53 47.7723 -114.0952				
12	12.529	64.119	120.000	762.000	1813.020	882.000
13	9999.000	9999.000	9999.000	9999.000	9999.000	8.918
14	0.124	1.485	0.412	33.000	38.800	29.200
21	80 3 1 2	19 47.7610 -114.1271				
22	9.516	141.154	30.000	387.000	1928.576	417.000
23	1.180	0.255	0.022	1.646	5.800	13.719
24	0.144	7.132	0.301	0.000	76.500	23.500
31	80 4 1 2	18 47.7532 -114.1463				
32	11.235	130.326	218.000	502.000	2385.565	720.000
33	9999.000	9999.000	9999.000	9999.000	9999.000	11.684
34	0.112	3.495	0.436	9999.000	9999.000	9999.000
41	80 5 1 2	19 47.7384 -114.1469				
42	10.710	130.662	238.000	446.000	2403.324	684.000
43	1.640	0.357	0.035	2.218	8.750	14.994
44	9999.000	9999.000	9999.000	1.200	67.300	31.500
51	80 6 1 2	15 47.7041 -114.1668				
52	8.316	365.148	99.000	772.000	3692.304	871.000
53	1.120	0.342	0.046	2.674	7.490	6.048
54	9999.000	9999.000	9999.000	9.000	40.900	50.100
61	80 7 1 2	30 FR				
62	8.558	234.956	166.000	1072.000	1853.974	1238.000
63	9999.000	9999.000	9999.000	9999.000	9999.000	7.158
64	0.035	1.381	0.245	20.000	70.200	9.800
71	80 8 1 2	80 48.0582 -114.1440				
72	9.048	300.672	116.000	1190.000	2180.568	1306.000
73	9999.000	9999.000	9999.000	9999.000	9999.000	6.960
74	0.032	2.304	0.291	2.700	41.800	15.500
81	80 10 1 2	65 47.8808 -114.0400				
82	6.732	448.052	107.000	692.000	2763.112	799.000
83	1.640	0.262	0.051	4.422	11.370	10.996
84	0.029	0.317	0.495	37.600	11.200	51.200
91	80 12 1 2	330 47.8790 -114.0710				
92	11.968	1062.160	248.000	1581.000	3844.720	1829.000
93	9999.000	9999.000	9999.000	9999.000	9999.000	16.456
94	0.172	0.973	0.607	0.000	58.600	61.400
101	80 13 1 2	20 47.7074 -114.1381				
102	17.640	48.510	295.000	756.000	2009.490	1051.000
103	9999.000	9999.000	9999.000	9999.000	9999.000	12.789
104	0.336	3.970	0.751	9999.000	9999.000	9999.000
111	80 15 1 2	15 47.7146 -114.1003				
112	5.488	54.880	194.000	444.000	1793.792	638.000
113	9999.000	9999.000	9999.000	9999.000	9999.000	12.152
114	0.324	4.732	0.700	7.000	66.000	27.000
121	80 17 1 2	8 47.7033 -114.0693				
122	3.640	135.360	469.000	673.000	1462.320	1142.000
123	9999.000	9999.000	9999.000	9999.000	9999.000	3.744
124	0.326	5.132	0.654	41.500	58.500	0.000
131	80 19 1 2	17 47.7357 -114.1677				
132	12.801	64.758	361.000	1098.000	2440.473	1459.000
133	9999.000	9999.000	9999.000	9999.000	9999.000	10.015
134	0.162	2.059	0.450	12.000	54.000	34.000
141	80 20 1 2	999 47.7649 -114.0858				
142	8.349	245.916	105.000	959.000	2793.120	1064.000
143	1.020	0.303	0.027	2.666	7.750	6.300
144	0.030	0.331	0.136	46.600	16.300	37.100
151	80 22 1 2	999 47.7403 -114.0945				
152	6.759	27.036	114.000	572.000	895.943	686.000
153	9999.000	9999.000	9999.000	9999.000	9999.000	6.834
154	0.057	1.389	0.286	62.600	37.400	0.000

```
161 80  26 1 2 999 47.7060 -114.0844
162     13.212     44.774    469.000    781.000   1318.118   1250.000
163   9999.000   9999.000   9999.000   9999.000   9999.000      9.615
164      0.339      4.092      0.791     10.700     89.300      0.000
171 80  29 1 2 999 47.7171 -114.0641
172     17.664     39.356    323.000    919.000   2618.880   1242.000
173      1.650      0.482      0.030      2.401      8.170     11.674
174      0.710      6.625      1.206      5.900     62.500     31.600
181 80  30 1 2   4 47.7251 -114.0619
182      3.012    251.502    346.000    927.000    501.498   1273.000
183   9999.000   9999.000   9999.000   9999.000   9999.000      2.786
184      0.044      0.328      0.298     60.000     19.600     20.400
191 80  31 1 2  16 47.7255 -114.1766
192     12.996     86.640    318.000   1329.000   2696.670   1647.000
193      1.800      0.645      0.007      2.318      8.370      9.891
194      0.175      2.304      0.521      6.900     72.000     21.100
201 80  32 1 2  16 47.7131 -114.1777
202     12.682     87.282     78.000   1437.000   2715.440   1515.000
203   9999.000   9999.000   9999.000   9999.000   9999.000      8.504
204      0.276      2.504      0.561     37.100     53.700      9.200
211 80  34 1 2  22 47.7239 -114.1393
212     19.422     41.085     40.000    670.000   1880.946    710.000
213   9999.000   9999.000   9999.000   9999.000   9999.000     14.193
214      0.078      1.180      0.370      1.300     98.700      0.000
221 80  36 1 2  20 47.7272 -114.1073
222     12.117     29.427     35.000    633.000   1335.755    668.000
223      1.120      0.040      0.017      2.671      6.930     11.021
224      0.239      2.912      0.614     13.100     86.900      0.000
231 80  38 1 1 132 47.8228 -114.0276
232     14.193   1124.235    143.000   2958.000   4207.104   3101.000
233   9999.000   9999.000   9999.000   9999.000   9999.000     10.010
234      0.162      2.380      0.524   9999.000   9999.000   9999.000
241 80  38 1 2 132 47.8228 -114.0276
242     15.393    427.339    361.000   2600.000   5369.958   2961.000
243   9999.000   9999.000   9999.000   9999.000   9999.000     11.943
244   9999.000   9999.000   9999.000      3.400     73.800     22.800
251 80  51 1 1 198 47.8212 -114.1849
252     14.160   2370.384    252.000   2425.000   5293.008   2777.000
253      1.920      0.499      0.219      3.372      9.900      9.204
254      0.274      1.497      0.634      0.000     30.000     70.000
261 80  51 1 2 198 47.8212 -114.1849
262     18.650   1065.288    235.000   1972.000   4919.124   2207.000
263      1.380      0.310      0.006      3.225      9.070     14.472
264      0.121      1.426      0.588      0.000     25.800     74.200
271 80  53 1 1  90 47.8155 -114.2254
272     18.798   1028.829    301.000   1752.000   5850.516   2053.000
273   9999.000   9999.000   9999.000   9999.000   9999.000      7,447
274      0.209      1.405      0.476     36.300     26.200     37.500
281 80  53 1 2  90 47.8155 -114.2254
282     14.880    308.016    549.000   1441.000   2688.072   1990.000
283   9999.000   9999.000   9999.000   9999.000   9999.000      7.599
284      0.208      1.620      0.419     27.900     37.100     35.000
291 80  54 1 2 105 47.8306 -114.2329
292     28.704    291.456    715.000   1325.000   3636.576   2040.000
293      1.370      0.379      0.046      3.537      9.960     12.218
294      0.260      2.024      0.674      0.900     23.800     75.300
301 80  55 1 1 115 47.8180 -114.2590
302     20.068   1641.424    485.000   2134.000   6254.988   2619.000
303   9999.000   9999.000   9999.000   9999.000   9999.000      9.490
304      0.330      2.264      0.714   9999.000   9999.000   9999.000
```

311	80 55 1 2	115 47.8180 -114.2590				
312	28.538	699.181	570.000	1757.000	5623.488	2327.000
313	9999.000	9999.000	9999.000	9999.000	9999.000	13.818
314	0.135	1.676	0.662	0.000	31.000	69.000
321	80 57 1 2	75 47.8046 -114.2962				
322	26.180	155.584	684.000	1016.000	1668.788	1700.000
323	1.850	0.578	0.032	2.814	8.310	8.602
324	0.248	2.270	0.756	1.600	49.200	49.200
331	80 59 1 2	65 47.8263 -114.3305				
332	25.704	74.088	677.000	877.000	2025.324	1554.000
333	1.830	0.514	0.021	2.640	10.410	10.508
334	0.283	3.106	0.740	9999.000	9999.000	9999.000
341	80 60 1 1	80 47.8377 -114.2682				
342	22.413	164.844	709.000	1338.000	2474.106	2047.000
343	9999.000	9999.000	9999.000	9999.000	9999.000	11.496
344	0.139	2.169	0.690	2.400	27.500	70.100
351	80 60 1 2	80 47.8377 -114.2682				
352	15.603	137.455	493.000	1068.000	2765.446	1561.000
353	9999.000	9999.000	9999.000	9999.000	9999.000	13.894
354	0.310	2.133	0.662	0.400	51.200	48.400
361	80 62 1 2	36 47.8587 -114.2684				
362	20.061	65.384	390.000	798.000	1860.472	1188.000
363	1.200	0.423	0.037	2.830	8.360	12.111
364	0.248	2.392	0.592	2.600	30.000	67.400
371	80 64 1 2	120 47.8014 -114.1724				
372	27.702	352.107	730.000	1366.000	4787.343	2096.000
373	1.890	0.674	0.041	3.212	10.390	12.903
374	9999.000	9999.000	9999.000	0.400	27.400	72.200
381	80 65 1 2	17 47.9028 -114.2018				
382	11.250	26.250	280.000	1542.000	1795.500	1822.000
383	1.780	0.579	0.017	2.798	7.710	9.975
384	9999.000	9999.000	9999.000	0.000	51.400	48.600
391	80 67 1 1	140 47.8730 -114.2053				
392	19.006	1439.339	252.000	2090.000	5393.318	2342.000
393	9999.000	9999.000	9999.000	9999.000	9999.000	12.719
394	0.180	1.140	0.566	0.000	24.800	75.200
401	80 67 1 2	140 47.8730 -114.2053				
402	19.552	1008.432	257.000	1917.000	6752.208	2174.000
403	1.460	0.021	0.090	3.978	9.690	14.138
404	0.149	1.172	0.517	0.000	29.200	70.800
411	80 68 1 1	115 47.8576 -114.2068				
412	21.000	380.250	575.000	1541.000	3507.000	2116.000
413	9999.000	9999.000	9999.000	9999.000	9999.000	12.450
414	9999.000	9999.000	9999.000	0.000	25.700	74.300
421	80 68 1 2	115 47.8576 -114.2068				
422	20.619	237.474	813.000	1327.000	3185.280	2140.000
423	9999.000	9999.000	9999.000	9999.000	9999.000	11.589
424	0.156	1.226	0.507	0.000	58.100	41.900
431	80 70 1 1	75 47.8557 -114.2433				
432	20.468	223.686	672.000	1324.000	3031.457	1996.000
433	9999.000	9999.000	9999.000	9999.000	9999.000	10.161
434	0.173	1.752	0.608	9999.000	9999.000	9999.000
441	80 70 1 2	75 47.8557 -114.2433				
442	19.100	117.800	678.000	1274.000	2440.000	1952.000
443	9999.000	9999.000	9999.000	9999.000	9999.000	9.312
444	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
451	80 71 1 1	240 47.8154 -114.1572				
452	10.094	1769.334	270.000	2104.000	2939.517	2374.000
453	9999.000	9999.000	9999.000	9999.000	9999.000	6.922
454	0.151	1.099	0.535	0.000	25.200	74.800

461	80 71 1 2 240 47.8154 -114.1572					
462	25.398	1429.758	295.000	2098.000	5148.324	2393.000
463	9999.000	9999.000	9999.000	9999.000	9999.000	12.027
464	9999.000	9999.000	9999.000	0.000	27.500	72.500
471	80 73 1 1 252 47.8445 -114.1586					
472	14.700	2490.915	191.000	2157.000	5063.415	2348.000
473	1.850	0.464	0.156	3.390	9.280	9.628
474	0.236	1.117	0.608	0.000	23.900	76.100
481	80 73 1 2 252 47.8445 -114.1586					
482	23.904	1706.895	269.000	2262.000	5410.521	2531.000
483	1.890	0.570	0.009	3.787	9.850	11.803
484	9999.000	9999.000	9999.000	0.000	30.000	70.000
491	80 75 1 1 180 47.8754 -114.1646					
492	13.500	1625.250	328.000	2117.000	2577.000	2445.000
493	9999.000	9999.000	9999.000	9999.000	9999.000	7.200
494	0.080	1.176	0.595	0.000	31.500	68.500
501	80 75 1 2 180 47.8754 -114.1646					
502	13.927	981.487	222.000	2251.000	4875.183	2473.000
503	9999.000	9999.000	9999.000	9999.000	9999.000	10.995
504	9999.000	9999.000	9999.000	0.000	28.700	71.300
511	80 78 1 1 300 47.7676 -114.0477					
512	15.309	2664.495	392.000	3225.000	6335.010	3617.000
513	9999.000	9999.000	9999.000	9999.000	9999.000	8.092
514	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
521	80 78 1 2 300 47.7676 -114.0477					
522	21.866	2712.892	344.000	2641.000	5902.312	2985.000
523	9999.000	9999.000	9999.000	9999.000	9999.000	13.421
524	0.061	1.624	0.608	0.500	22.200	77.300
531	80 79 1 1 295 47.8081 -114.0367					
532	15.523	2327.633	135.000	3205.000	5879.132	3340.000
533	9999.000	9999.000	9999.000	9999.000	9999.000	8.742
534	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
541	80 79 1 2 295 47.8081 -114.0367					
542	23.250	1827.750	416.000	2013.000	4573.500	2429.000
543	9999.000	9999.000	9999.000	9999.000	9999.000	14.400
544	0.095	1.195	0.487	0.000	27.500	72.500
551	80 81 1 1 999 47.7850 -114.0783					
552	8.107	218.152	337.000	800.000	1094.445	1137.000
553	9999.000	9999.000	9999.000	9999.000	9999.000	3.832
554	0.092	0.818	0.277	9999.000	9999.000	9999.000
561	80 81 1 2 999 47.7850 -114.0783					
562	7.450	673.480	138.000	1015.000	3158.800	1153.000
563	9999.000	9999.000	9999.000	9999.000	9999.000	9.908
564	0.010	0.420	0.730	69.300	17.600	13.100
571	80 82 1 2 999 47.7553 -114.0762					
572	4.476	70.870	56.000	881.000	1403.972	937.000
573	9999.000	9999.000	9999.000	9999.000	9999.000	3.432
574	0.050	0.700	0.186	54.500	42.400	3.100
581	80 83 1 2 999 47.7417 -114.0528					
582	3.755	44.309	53.000	540.000	408.544	593.000
583	1.290	0.448	0.011	1.981	6.310	1.577
584	0.000	0.000	0.032	95.500	0.500	0.000
591	80 85 1 1 999 47.7733 -114.0239					
592	9.711	472.851	271.000	2825.000	2098.323	3096.000
593	1.810	0.494	0.271	3.380	9.490	7.321
594	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
601	80 85 1 2 999 47.7733 -114.0239					
602	16.280	1844.080	191.000	1846.000	4417.800	2137.000
603	1.760	0.377	0.212	4.427	9.890	12.876
604	0.145	1.748	0.604	0.000	51.500	48.500

611	80 86 1 1	999 47.7812	-114.0415			
612	16.478	1387.897	394.000	2501.000	5515.636	2895.000
613	9999.000	9999.000	9999.000	9999.000	9999.000	12.209
614	0.241	1.440	0.623	0.000	21.800	78.200
621	80 86 1 2	999 47.7812	-114.0415			
622	21.257	1817.107	510.000	1751.000	5346.502	2261.000
623	9999.000	9999.000	9999.000	9999.000	9999.000	15.393
624	0.220	1.585	0.633	0.000	21.000	79.000
631	80 87 1 2	999 47.7934	-114.0670			
632	9.750	477.750	497.000	1740.000	2172.000	2237.000
633	1.500	0.376	0.212	4.420	12.760	7.425
634	0.357	0.443	0.451	0.000	18.000	82.000
641	80 88 1 2	252 47.8309	-114.0374			
642	16.302	3172.962	356.000	2990.000	6166.602	3346.000
643	1.810	0.539	0.209	3.146	9.540	13.931
644	0.175	1.247	0.560	0.000	30.000	70.000
651	80 91 1 2	205 47.7898	-114.1145			
652	17.592	1771.661	278.000	2252.000	6458.463	2530.000
653	1.370	0.358	0.110	3.550	8.870	14.293
654	0.181	1.239	0.642	0.000	25.800	74.200
661	80 92 1 1	216 47.7969	-114.1401			
662	14.980	2896.383	278.000	2782.000	5703.635	3060.000
663	9999.000	9999.000	9999.000	9999.000	9999.000	11.010
664	0.283	1.796	0.672	0.000	33.700	66.300
671	80 92 1 2	216 47.7969	-114.1401			
672	18.275	2175.456	318.000	2276.000	5592.150	2594.000
673	9999.000	9999.000	9999.000	9999.000	9999.000	14.839
674	0.240	1.653	0.639	0.700	29.700	69.600
681	80 93 1 1	240 47.7992	-114.1040			
682	14.920	2727.376	200.000	3103.000	5972.476	3303.000
683	9999.000	9999.000	9999.000	9999.000	9999.000	10.519
684	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
691	80 93 1 2	240 47.7992	-114.1040			
692	16.280	2641.800	246.000	2167.000	5680.240	2413.000
693	9999.000	9999.000	9999.000	9999.000	9999.000	15.984
694	0.182	1.408	0.561	0.000	20.400	79.600
701	80 94 1 1	258 47.8208	-114.0753			
702	15.582	2453.794	327.000	2765.000	4199.720	3092.000
703	9999.000	9999.000	9999.000	9999.000	9999.000	9.572
704	0.163	1.354	0.627	0.000	32.100	67.900
711	80 94 1 2	258 47.8208	-114.0753			
712	26.215	2125.662	128.000	2253.000	5291.685	2381.000
713	9999.000	9999.000	9999.000	9999.000	9999.000	14.381
714	0.200	1.280	0.605	0.000	28.000	72.000
721	80 96 1 1	270 47.8124	-114.1310			
722	15.708	2612.016	108.000	2889.000	5068.448	2997.000
723	9999.000	9999.000	9999.000	9999.000	9999.000	15.858
724	0.201	1.449	0.641	0.000	30.200	69.800
731	80 96 1 2	270 47.8124	-114.1310			
732	21.000	2304.750	359.000	2115.000	5337.000	2474.000
733	9999.000	9999.000	9999.000	9999.000	9999.000	15.600
734	0.199	1.275	0.577	0.000	41.600	58.400
741	80 98 1 1	270 47.8277	-114.1105			
742	15.666	2797.500	112.000	3142.000	5180.370	3254.000
743	2.000	0.432	0.271	3.172	10.180	11.414
744	0.216	1.773	0.596	0.000	33.800	66.200
751	80 98 1 2	270 47.8277	-114.1105			
752	19.552	1946.928	555.000	1805.000	5599.392	2360.000
753	1.840	0.081	0.099	3.490	9.910	15.942
754	0.208	1.309	0.603	0.000	36.400	63.600

761	80	99 1 1	270	47.8340	-114.0747		
762	15.666	2396.152	281.000	2331.000	4326.800	2612.000	
763	9999.000	9999.000	9999.000	9999.000	9999.000	11.190	
764	0.167	1.398	0.617	0.000	36.600	63.400	
771	80	99 1 2	270	47.8340	-114.0747		
772	20.860	2830.255	384.000	2079.000	5071.960	2463.000	
773	9999.000	9999.000	9999.000	9999.000	9999.000	13.485	
774	0.166	1.000	0.557	0.000	26.600	73.400	
781	80	101 1 2	348	47.8621	-114.0689		
782	29.055	1536.935	374.000	1191.000	5392.310	2285.000	
783	9999.000	9999.000	9999.000	9999.000	9999.000	14.676	
784	0.108	1.574	0.579	0.000	25.200	74.800	
791	80	102 1 2	180	47.8666	-114.0367		
792	19.526	2404.702	425.000	2384.000	5793.214	2809.000	
793	9999.000	9999.000	9999.000	9999.000	9999.000	15.921	
794	0.186	1.282	0.637	4.000	27.800	68.200	
801	80	105 1 1	264	47.8490	-114.1296		
802	15.624	7030.800	638.000	1905.000	4522.032	2543.000	
803	9999.000	9999.000	9999.000	9999.000	9999.000	11.234	
804	0.345	1.421	0.605	0.000	29.100	70.900	
811	80	105 1 2	264	47.8490	-114.1296		
812	23.374	1462.760	437.000	1878.000	4271.410	2315.000	
813	9999.000	9999.000	9999.000	9999.000	9999.000	13.346	
814	0.163	1.074	0.563	0.000	24.900	75.100	
821	80	106 1 1	258	47.8466	-114.0986		
822	15.040	2235.696	934.000	1487.000	3568.992	2421.000	
823	1.890	0.454	0.389	3.011	9.580	10.378	
824	0.163	0.963	0.448	0.000	34.300	65.700	
831	80	106 1 2	258	47.8466	-114.0986		
832	22.500	2107.500	225.000	2167.000	5241.000	2392.000	
833	1.820	0.535	0.107	3.060	9.010	14.550	
834	9999.000	9999.000	9999.000	0.000	27.200	72.800	
841	80	110 1 1	155	47.8723	-114.1318		
842	16.236	1642.050	463.000	1513.000	1887.804	1976.000	
843	1.370	0.335	0.523	3.683	9.680	9.889	
844	0.106	1.064	0.504	9999.000	9999.000	9999.000	
851	80	110 1 2	155	47.8723	-114.1318		
852	14.780	1698.961	163.000	1775.000	3001.079	1938.000	
853	1.970	0.483	0.079	3.496	9.840	12.194	
854	0.025	0.819	0.508	0.000	57.700	42.300	
861	80	111 1 1	160	47.8759	-114.1019		
862	14.212	2371.908	426.000	2193.000	4316.708	2619.000	
863	9999.000	9999.000	9999.000	9999.000	9999.000	10.023	
864	0.051	1.178	0.491	0.000	34.000	66.000	
871	80	111 1 2	160	47.8759	-114.1019		
872	20.300	1529.000	513.000	1485.000	4051.000	1898.000	
873	9999.000	9999.000	9999.000	9999.000	9999.000	9.312	
874	9999.000	9999.000	9999.000	0.000	47.400	52.600	
881	81	112 1 2	40	47.8993	-114.0343		
882	6.180	125.200	145.000	967.000	808.500	1112.000	
883	9999.000	9999.000	9999.000	9999.000	9999.000	1.394	
884	9999.000	9999.000	9999.000	87.200	9.800	3.000	
891	81	114 1 1	180	47.9133	-114.1622		
892	13.100	2260.000	162.000	2003.000	4162.000	2165.000	
893	9999.000	9999.000	9999.000	9999.000	9999.000	6.670	
894	9999.000	9999.000	9999.000	0.000	32.600	67.400	
901	81	114 1 2	180	47.9133	-114.1622		
902	13.200	802.700	349.000	1534.000	3862.000	1883.000	
903	9999.000	9999.000	9999.000	9999.000	9999.000	10.820	
904	9999.000	9999.000	9999.000	0.000	30.800	69.200	

911	81 115 1 1	110 47.9371 -114.1752				
912	13.100	1627.000	350.000	1988.000	3532.000	2238.000
913	9999.000	9999.000	9999.000	9999.000	9999.000	7.050
914	9999.000	9999.000	9999.000	0.000	36.200	63.800
921	81 115 1 2	110 47.9371 -114.1752				
922	16.800	589.000	348.000	1315.000	4213.000	1663.000
923	9999.000	9999.000	9999.000	9999.000	9999.000	9.691
924	9999.000	9999.000	9999.000	0.000	41.300	58.700
931	81 116 1 1	115 47.9537 -114.1766				
932	14.500	1130.000	372.000	1740.000	3683.000	2112.000
933	9999.000	9999.000	9999.000	9999.000	9999.000	7.049
934	9999.000	9999.000	9999.000	0.000	37.300	62.700
941	81 116 1 2	115 47.9537 -114.1766				
942	14.000	512.900	350.000	1070.000	3707.000	1420.000
943	9999.000	9999.000	9999.000	9999.000	9999.000	8.936
944	9999.000	9999.000	9999.000	0.000	37.600	62.400
951	81 117 1 1	140 47.9733 -114.1664				
952	14.000	999.000	252.000	1588.000	3868.000	1840.000
953	9999.000	9999.000	9999.000	9999.000	9999.000	6.294
954	9999.000	9999.000	9999.000	0.000	36.100	63.900
961	81 117 1 2	140 47.9733 -114.1664				
962	13.300	627.800	274.000	1342.000	4739.000	1616.000
963	9999.000	9999.000	9999.000	9999.000	9999.000	9.314
964	9999.000	9999.000	9999.000	0.000	37.300	62.700
971	81 118 1 1	70 47.9915 -114.1808				
972	12.700	1756.000	232.000	1876.000	4447.000	2108.000
973	9999.000	9999.000	9999.000	9999.000	9999.000	6.293
974	9999.000	9999.000	9999.000	0.000	38.200	61.800
981	81 118 1 2	70 47.9915 -114.1808				
982	17.600	375.800	417.000	1380.000	4428.000	1797.000
983	9999.000	9999.000	9999.000	9999.000	9999.000	9.312
984	9999.000	9999.000	9999.000	0.000	36.400	63.600
991	81 119 1 1	100 48.0034 -114.1880				
992	11.400	1515.000	217.000	1795.000	2806.000	2012.000
993	9999.000	9999.000	9999.000	9999.000	9999.000	6.668
994	9999.000	9999.000	9999.000	0.000	42.400	57.600
1001	81 119 1 2	100 48.0034 -114.1880				
1002	13.000	659.800	398.000	1537.000	3849.000	1935.000
1003	9999.000	9999.000	9999.000	9999.000	9999.000	11.138
1004	9999.000	9999.000	9999.000	0.000	38.100	61.900
1011	81 120 1 1	55 48.0102 -114.2033				
1012	14.400	671.200	493.000	1404.000	3228.000	1897.000
1013	9999.000	9999.000	9999.000	9999.000	9999.000	6.672
1014	9999.000	9999.000	9999.000	0.000	39.100	60.900
1021	81 120 1 2	55 48.0102 -114.2033				
1022	22.500	290.700	585.000	1065.000	2901.000	1650.000
1023	9999.000	9999.000	9999.000	9999.000	9999.000	8.177
1024	9999.000	9999.000	9999.000	0.000	33.300	64.300
1031	81 122 1 1	250 47.9021 -114.0483				
1032	22.100	2132.000	513.000	1542.000	3853.000	2061.000
1033	9999.000	9999.000	9999.000	9999.000	9999.000	8.932
1034	9999.000	9999.000	9999.000	1.800	26.900	71.300
1041	81 122 1 2	250 47.9021 -114.0483				
1042	15.900	1397.000	784.000	1250.000	3272.000	2034.000
1043	9999.000	9999.000	9999.000	9999.000	9999.000	11.944
1044	9999.000	9999.000	9999.000	1.200	24.900	73.900
1051	81 123 1 1	300 47.9013 -114.0617				
1052	14.200	2280.000	683.000	1397.000	3437.000	2060.000
1053	9999.000	9999.000	9999.000	9999.000	9999.000	8.554
1054	9999.000	9999.000	9999.000	0.000	30.700	69.300

```
1061 81 123 1 2 300 47.9013 -114.0617
1062     13.300  2125.000   529.000  1463.000  5792.000  1992.000
1063   9999.000  9999.000  9999.000  9999.000  9999.000    11.573
1064   9999.000  9999.000  9999.000     0.000    23.300    76.700
1071 81 124 1 1 300 47.9016 -114.0825
1072     13.900  2386.000   161.000  2028.000  4465.000  2189.000
1073   9999.000  9999.000  9999.000  9999.000  9999.000     9.305
1074   9999.000  9999.000  9999.000     0.000    32.400    67.700
1081 81 124 1 2 300 47.9016 -114.0825
1082     13.200  1510.000   328.000  1617.000  3850.000  1945.000
1083   9999.000  9999.000  9999.000  9999.000  9999.000    13.832
1084   9999.000  9999.000  9999.000     0.000    35.200    64.800
1091 81 125 1 1 180 47.9015 -114.1126
1092     13.800  1508.000   175.000  2553.000  4145.000  2728.000
1093   9999.000  9999.000  9999.000  9999.000  9999.000     6.295
1094   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1101 81 125 1 2 180 47.9015 -114.1126
1102     19.400  1060.000   538.000  1524.000  3827.000  2062.000
1103   9999.000  9999.000  9999.000  9999.000  9999.000     9.307
1104   9999.000  9999.000  9999.000     0.000    28.800    71.200
1111 81 126 1 1 145 47.9008 -114.1329
1112     13.800  1781.000   166.000  2302.000  4356.000  2468.000
1113   9999.000  9999.000  9999.000  9999.000  9999.000     6.670
1114   9999.000  9999.000  9999.000     0.000    35.400    64.600
1121 81 126 1 2 145 47.9008 -114.1329
1122     23.500   806.100   426.000  1548.000  3688.000  1974.000
1123   9999.000  9999.000  9999.000  9999.000  9999.000     8.931
1124   9999.000  9999.000  9999.000     0.000    31.100    68.900
1131 81 127 1 1 160 47.9281 -114.1558
1132     13.500  1877.000   525.000  1619.000  3838.000  2144.000
1133   9999.000  9999.000  9999.000  9999.000  9999.000     7.422
1134   9999.000  9999.000  9999.000     0.000    36.700    63.300
1141 81 127 1 2 160 47.9281 -114.1558
1142     16.600   816.200   387.000  1731.000  4883.000  2118.000
1143   9999.000  9999.000  9999.000  9999.000  9999.000    10.064
1144   9999.000  9999.000  9999.000     0.000    41.500    58.500
1151 81 128 1 1 135 47.9261 -114.1222
1152     13.200  1197.000   171.000  2370.000  3786.000  2541.000
1153   9999.000  9999.000  9999.000  9999.000  9999.000     6.669
1154   9999.000  9999.000  9999.000     0.000    37.400    62.600
1161 81 128 1 2 135 47.9261 -114.1222
1162     19.400   880.400   178.000  1856.000  3383.000  2034.000
1163   9999.000  9999.000  9999.000  9999.000  9999.000     9.307
1164   9999.000  9999.000  9999.000     0.000    40.600    59.400
1171 81 129 1 1 320 47.9222 -114.0865
1172     12.000  1678.000   358.000  2099.000  3655.000  2447.000
1173   9999.000  9999.000  9999.000  9999.000  9999.000     8.181
1174   9999.000  9999.000  9999.000     0.000    40.900    59.100
1181 81 129 1 2 320 47.9222 -114.0865
1182     12.600  1382.000   329.000  1587.000  3541.000  1916.000
1183   9999.000  9999.000  9999.000  9999.000  9999.000    12.325
1184   9999.000  9999.000  9999.000     0.000    41.200    58.800
1191 81 130 1 1 250 47.9234 -114.0602
1192     15.400  2258.000   458.000  2181.000  4459.000  2639.000
1193   9999.000  9999.000  9999.000  9999.000  9999.000     5.165
1194   9999.000  9999.000  9999.000     0.000    27.400    72.600
1201 81 130 1 2 250 47.9234 -114.0602
1202     17.500  2517.000   205.000  2305.000  6294.000  2510.000
1203   9999.000  9999.000  9999.000  9999.000  9999.000    10.059
1204   9999.000  9999.000  9999.000     0.000    22.500    77.500
```

1211	81 131 1 1	155	47.9242	-114.0391		
1212	16.000	1876.000	348.000	1911.000	3986.000	2259.000
1213	9999.000	9999.000	9999.000	9999.000	9999.000	5.163
1214	9999.000	9999.000	9999.000	1.000	41.400	57.600
1221	81 131 1 2	155	47.9242	-114.0391		
1222	14.800	1635.000	346.000	1722.000	3699.000	2068.000
1223	9999.000	9999.000	9999.000	9999.000	9999.000	10.438
1224	9999.000	9999.000	9999.000	0.000	24.300	75.700
1231	81 132 1 1	200	47.9558	-114.0430		
1232	16.400	2381.000	220.000	2163.000	4230.000	2383.000
1233	9999.000	9999.000	9999.000	9999.000	9999.000	9.685
1234	9999.000	9999.000	9999.000	0.000	33.400	66.600
1241	81 132 1 2	200	47.9558	-114.0430		
1242	23.100	1994.000	273.000	1876.000	4575.000	2155.000
1243	9999.000	9999.000	9999.000	9999.000	9999.000	10.063
1244	9999.000	9999.000	9999.000	0.000	27.500	72.500
1251	81 133 1 1	185	47.9561	-114.0610		
1252	14.600	2124.000	275.000	2248.000	2937.000	2523.000
1253	9999.000	9999.000	9999.000	9999.000	9999.000	4.787
1254	9999.000	9999.000	9999.000	0.000	40.000	60.000
1261	81 133 1 2	185	47.9561	-114.0610		
1262	20.100	1752.000	472.000	1804.000	4358.000	2276.000
1263	9999.000	9999.000	9999.000	9999.000	9999.000	8.930
1264	9999.000	9999.000	9999.000	0.000	29.500	70.500
1271	81 134 1 1	200	47.9561	-114.0954		
1272	10.000	1263.000	427.000	1572.000	3728.000	1999.000
1273	9999.000	9999.000	9999.000	9999.000	9999.000	8.553
1274	9999.000	9999.000	9999.000	0.000	39.500	60.500
1281	81 134 1 2	200	47.9561	-114.0954		
1282	13.400	1034.000	157.000	1862.000	3680.000	2219.000
1283	9999.000	9999.000	9999.000	9999.000	9999.000	10.062
1284	9999.000	9999.000	9999.000	0.000	43.900	56.100
1291	81 135 1 1	140	47.9564	-114.1301		
1292	13.000	1651.000	146.000	2008.000	3583.000	2154.000
1293	9999.000	9999.000	9999.000	9999.000	9999.000	6.295
1294	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000
1301	81 135 1 2	140	47.9564	-114.1301		
1302	16.200	590.800	207.000	1545.000	3347.000	1752.000
1303	9999.000	9999.000	9999.000	9999.000	9999.000	8.178
1304	9999.000	9999.000	9999.000	0.000	49.200	50.800
1311	81 136 1 1	100	47.9561	-114.1515		
1312	13.300	1382.000	262.000	2137.000	3839.000	2399.000
1313	9999.000	9999.000	9999.000	9999.000	9999.000	5.917
1314	9999.000	9999.000	9999.000	0.000	43.300	56.700
1321	81 136 1 2	100	47.9561	-114.1515		
1322	18.100	641.100	278.000	1630.000	3529.000	1908.000
1323	9999.000	9999.000	9999.000	9999.000	9999.000	8.177
1324	9999.000	9999.000	9999.000	0.000	44.800	55.200
1331	81 137 1 1	125	47.9764	-114.1513		
1332	11.400	890.400	222.000	2035.000	3859.000	2257.000
1333	9999.000	9999.000	9999.000	9999.000	9999.000	7.426
1334	9999.000	9999.000	9999.000	0.000	39.900	60.100
1341	81 137 1 2	125	47.9764	-114.1513		
1342	14.300	621.500	398.000	1388.000	3568.000	1766.000
1343	9999.000	9999.000	9999.000	9999.000	9999.000	8.930
1344	9999.000	9999.000	9999.000	0.000	43.000	57.000
1351	81 138 1 1	90	47.9785	-114.1202		
1352	12.700	786.300	224.000	1843.000	3403.000	2067.000
1353	9999.000	9999.000	9999.000	9999.000	9999.000	5.919
1354	9999.000	9999.000	9999.000	9999.000	9999.000	9999.000

```
1361 81 138 1 2  90 47.9785 -114.1202
1362     17.100   387.800   287.000  1483.000  3108.000  1770.000
1363   9999.000  9999.000  9999.000  9999.000  9999.000    10.819
1364   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1371 81 139 1 1 200 47.9811 -114.0840
1372     10.200   931.200   192.000  1794.000  3568.000  1986.000
1373   9999.000  9999.000  9999.000  9999.000  9999.000    10.814
1374   9999.000  9999.000  9999.000     0.000    41.000    59.000
1381 81 139 1 2 200 47.9811 -114.0840
1382     12.900   772.300   320.000  1554.000  3390.000  1874.000
1383   9999.000  9999.000  9999.000  9999.000  9999.000    13.830
1384   9999.000  9999.000  9999.000     0.000    41.200    58.800
1391 81 140 1 1  95 47.9824 -114.0588
1392      6.740   189.600   232.000  1011.000   675.800  1243.000
1393   9999.000  9999.000  9999.000  9999.000  9999.000     3.290
1394   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1401 81 140 1 2  95 47.9824 -114.0588
1402      5.980   105.400   219.000   979.000   711.000  1198.000
1403   9999.000  9999.000  9999.000  9999.000  9999.000     4.787
1404   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1411 81 141 1 1 190 47.9900 -114.0523
1412     19.900   726.000   312.000  2077.000  4137.000  2339.000
1413   9999.000  9999.000  9999.000  9999.000  9999.000     8.175
1414   9999.000  9999.000  9999.000     5.200    37.600    57.200
1421 81 141 1 2 190 47.9900 -114.0523
1422     25.600   524.900   273.000  1774.000  4768.000  2052.000
1423   9999.000  9999.000  9999.000  9999.000  9999.000    10.439
1424   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1431 81 143 1 1 110 47.9985 -114.0769
1432     17.900   661.700   208.000  1970.000  3218.000  2178.000
1433   9999.000  9999.000  9999.000  9999.000  9999.000     7.425
1434   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1441 81 143 1 2 110 47.9985 -114.0769
1442     17.500   999.900   208.000  1918.000  3721.000  2126.000
1443   9999.000  9999.000  9999.000  9999.000  9999.000     9.683
1444   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1451 81 144 1 1 210 47.9968 -114.0965
1452     14.900  1891.000   533.000  1439.000  3565.000  1972.000
1453   9999.000  9999.000  9999.000  9999.000  9999.000     6.294
1454   9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1461 81 144 1 2 210 47.9968 -114.0965
1462     15.600   831.900   266.000  1515.000  3569.000  1781.000
1463   9999.000  9999.000  9999.000  9999.000  9999.000    11.191
1464   9999.000  9999.000  9999.000     0.000    36.900    63.100
1471 81 145 1 1 290 47.9927 -114.1131
1472     12.800  2071.000   227.000  1524.000  3478.000  1751.000
1473   9999.000  9999.000  9999.000  9999.000  9999.000     6.294
1474   9999.000  9999.000  9999.000     0.000    51.600    48.400
1481 81 145 1 2 290 47.9927 -114.1131
1482     12.700   634.600   259.000  1456.000  4183.000  1715.000
1483   9999.000  9999.000  9999.000  9999.000  9999.000     9.689
1484   9999.000  9999.000  9999.000     0.000    47.200    52.700
1491 81 146 1 1  75 47.9931 -114.1424
1492      8.810   907.700   401.000  1417.000  2949.000  1818.000
1493   9999.000  9999.000  9999.000  9999.000  9999.000     4.409
1494   9999.000  9999.000  9999.000     1.000    57.000    42.000
1501 81 146 1 2  75 47.9931 -114.1424
1502     11.200   261.800   269.000  1541.000  2503.000  1810.000
1503   9999.000  9999.000  9999.000  9999.000  9999.000     7.425
1504   9999.000  9999.000  9999.000     2.200    70.500    27.300
```

```
1511 81 147 1 1  70 48.0147 -114.1608
1512    10.500  1044.000   290.000  2208.000  2946.000  2498.000
1513  9999.000  9999.000  9999.000  9999.000  9999.000     5.917
1514  9999.000  9999.000  9999.000     0.000    61.300    38.700
1521 81 147 1 2  70 48.0147 -114.1608
1522    12.000   245.200   248.000   932.000  2339.000  1080.000
1523  9999.000  9999.000  9999.000  9999.000  9999.000     6.673
1524  9999.000  9999.000  9999.000     1.700    65.400    32.900
1531 81 148 1 1 185 48.0145 -114.1337
1532     9.250  1510.000   368.000  1803.000  4000.000  2171.000
1533  9999.000  9999.000  9999.000  9999.000  9999.000     7.423
1534  9999.000  9999.000  9999.000     0.000    70.400    29.600
1541 81 148 1 2 185 48.0145 -114.1337
1542    10.400   430.400   120.000  1276.000  2810.000  1398.000
1543  9999.000  9999.000  9999.000  9999.000  9999.000     7.422
1544  9999.000  9999.000  9999.000     0.000    70.500    29.500
1551 81 149 1 1 235 48.0172 -114.1030
1552    12.100  1767.000   377.000  1573.000  4471.000  1950.000
1553  9999.000  9999.000  9999.000  9999.000  9999.000     8.179
1554  9999.000  9999.000  9999.000     0.000    56.000    44.000
1561 81 149 1 2 235 48.0172 -114.1030
1562    13.600   449.500   204.000  1244.000  3869.000  1448.000
1563  9999.000  9999.000  9999.000  9999.000  9999.000    10.816
1564  9999.000  9999.000  9999.000     1.200    44.300    54.500
1571 81 150 1 1 155 48.0186 -114.0853
1572    13.400  1740.000   182.000  2324.000  3511.000  2506.000
1573  9999.000  9999.000  9999.000  9999.000  9999.000     7.802
1574  9999.000  9999.000  9999.000     0.000    49.900    50.100
1581 81 150 1 2 155 48.0186 -114.0853
1582    17.700   648.200   372.000  1523.000  3998.000  1895.000
1583  9999.000  9999.000  9999.000  9999.000  9999.000     8.177
1584  9999.000  9999.000  9999.000     0.000    47.200    52.400
1591 81 151 1 1 120 48.0376 -114.0864
1592    12.200  1884.000   235.000  2147.000  4154.000  2382.000
1593  9999.000  9999.000  9999.000  9999.000  9999.000     5.918
1594  9999.000  9999.000  9999.000     3.100    59.100    37.800
1601 81 151 1 2 120 48.0376 -114.0864
1602    17.500   456.100   428.000  1417.000  3080.000  1845.000
1603  9999.000  9999.000  9999.000  9999.000  9999.000     9.635
1604  9999.000  9999.000  9999.000     3.300    51.100    45.600
1611 81 152 1 1  12 48.0507 -114.0882
1612     9.720   257.800   429.000  1486.000  1106.000  2015.000
1613  9999.000  9999.000  9999.000  9999.000  9999.000     3.279
1614  9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
1621 81 152 1 2  12 48.0507 -114.0882
1622     7.170   124.500   325.000  1390.000   972.300  1715.000
1623  9999.000  9999.000  9999.000  9999.000  9999.000     3.279
1624  9999.000  9999.000  9999.000    77.700    16.500     5.800
1631 81 153 1 2  20 48.0500 -114.1055
1632     7.990   179.400   385.000  1629.000  1761.000  2014.000
1633  9999.000  9999.000  9999.000  9999.000  9999.000     4.409
1634  9999.000  9999.000  9999.000    42.100    48.700     9.200
1641 81 154 1 2  10 48.0416 -114.1196
1642     6.450   174.500    27.000  1097.000  1512.000  1124.000
1643  9999.000  9999.000  9999.000  9999.000  9999.000     5.163
1644  9999.000  9999.000  9999.000    65.500    26.500     8.000
1651 81 155 1 1  45 48.0330 -114.1255
1652     9.440   365.300   338.000  2030.000  2203.000  2368.000
1653  9999.000  9999.000  9999.000  9999.000  9999.000    11.191
1654  9999.000  9999.000  9999.000  9999.000  9999.000  9999.000
```

```
1661 81 155 1 2  45 48.0330 -114.1255
1662      9.210    304.100   294.000  1819.000  2355.000  2113.000
1663   9999.000   9999.000  9999.000  9999.000  9999.000     7.425
1664   9999.000   9999.000  9999.000     8.500    73.400    18.100
1671 81 156 1 2  12 48.0360 -114.1561
1672      7.050    131.100   280.000  1285.000   659.800  1565.000
1673   9999.000   9999.000  9999.000  9999.000  9999.000     2.902
1674   9999.000   9999.000  9999.000    86.200     9.600     4.200
1681 81 157 1 1  95 48.0335 -114.1859
1682     13.200   1395.000   252.000  1764.000  4027.000  2016.000
1683   9999.000   9999.000  9999.000  9999.000  9999.000     6.296
1684   9999.000   9999.000  9999.000     0.000    50.600    49.400
1691 81 157 1 2  85 48.0335 -114.1859
1692     12.100    577.800   316.000  1377.000  4188.000  1693.000
1693   9999.000   9999.000  9999.000  9999.000  9999.000    13.836
1694   9999.000   9999.000  9999.000  9999.000  9999.000  9999.000
1701 81 158 1 1  65 48.0307 -114.2162
1702     17.600   1136.000   329.000  1695.000  4155.000  2024.000
1703   9999.000   9999.000  9999.000  9999.000  9999.000     6.295
1704   9999.000   9999.000  9999.000     0.000    39.300    60.700
1711 81 158 1 2  65 48.0307 -114.2162
1712     20.200    493.500   374.000  1339.000  4122.000  1713.000
1713   9999.000   9999.000  9999.000  9999.000  9999.000    10.060
1714   9999.000   9999.000  9999.000     0.000    35.700    64.300
1721 81 159 1 1  70 48.0540 -114.2254
1722     24.700   1633.000   232.000  1237.000  3093.000  1469.000
1723   9999.000   9999.000  9999.000  9999.000  9999.000     5.917
1724   9999.000   9999.000  9999.000     0.000    41.000    59.000
1731 81 159 1 2  70 48.0540 -114.2254
1732     21.500    587.300   125.000   777.000  4477.000   902.000
1733   9999.000   9999.000  9999.000  9999.000  9999.000    10.440
1734   9999.000   9999.000  9999.000     0.000    42.700    57.300
1741 81 160 1 1  40 48.0665 -114.2341
1742     72.100    492.000   496.000  1695.000  5085.000  2191.000
1743   9999.000   9999.000  9999.000  9999.000  9999.000     6.293
1744   9999.000   9999.000  9999.000  9999.000  9999.000  9999.000
1751 81 160 1 2  40 48.0665 -114.2341
1752     52.300    233.500   332.000  1434.000  3385.000  1766.000
1753   9999.000   9999.000  9999.000  9999.000  9999.000     8.554
1754   9999.000   9999.000  9999.000     0.900    49.700    49.400
1761 81 161 1 2  10 48.0629 -114.2002
1762     12.700   1646.000   124.000  1618.000   594.400  1842.000
1763   9999.000   9999.000  9999.000  9999.000  9999.000     2.901
1764   9999.000   9999.000  9999.000    96.800     8.800     4.400
1771 81 162 1 1  20 48.0594 -114.1969
1772     11.900    262.600    53.000  1181.000  1240.000  1234.000
1773   9999.000   9999.000  9999.000  9999.000  9999.000     4.034
1774   9999.000   9999.000  9999.000    67.600    18.800    13.600
1781 81 162 1 2  20 48.0594 -114.1969
1782     13.300    112.400    76.000  1080.000   845.800  1156.000
1783   9999.000   9999.000  9999.000  9999.000  9999.000     4.032
1784   9999.000   9999.000  9999.000    72.900    17.000    10.100
1791 81 163 1 1  55 48.0606 -114.1727
1792     10.300    717.200   355.000  1431.000  2333.000  1787.000
1793   9999.000   9999.000  9999.000  9999.000  9999.000     7.046
1794   9999.000   9999.000  9999.000     0.000    68.700    31.300
1801 81 163 1 2  55 48.0606 -114.1727
1802     12.900    455.800   166.000  1521.000  3254.000  1687.000
1803   9999.000   9999.000  9999.000  9999.000  9999.000     9.311
1804   9999.000   9999.000  9999.000     0.000    69.300    30.700
```